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1955 - 1956

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 900 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees	*Annual Dues*
Members	$ 3.00	$ 6.00
Juniors	1.00	3.00
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This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

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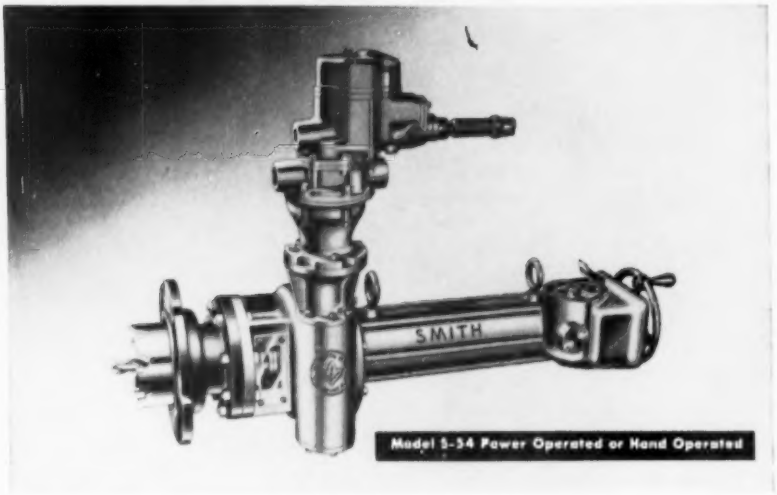

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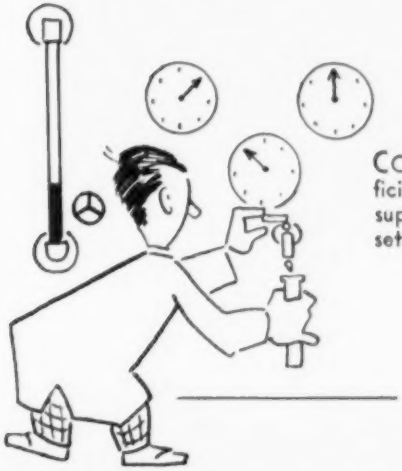

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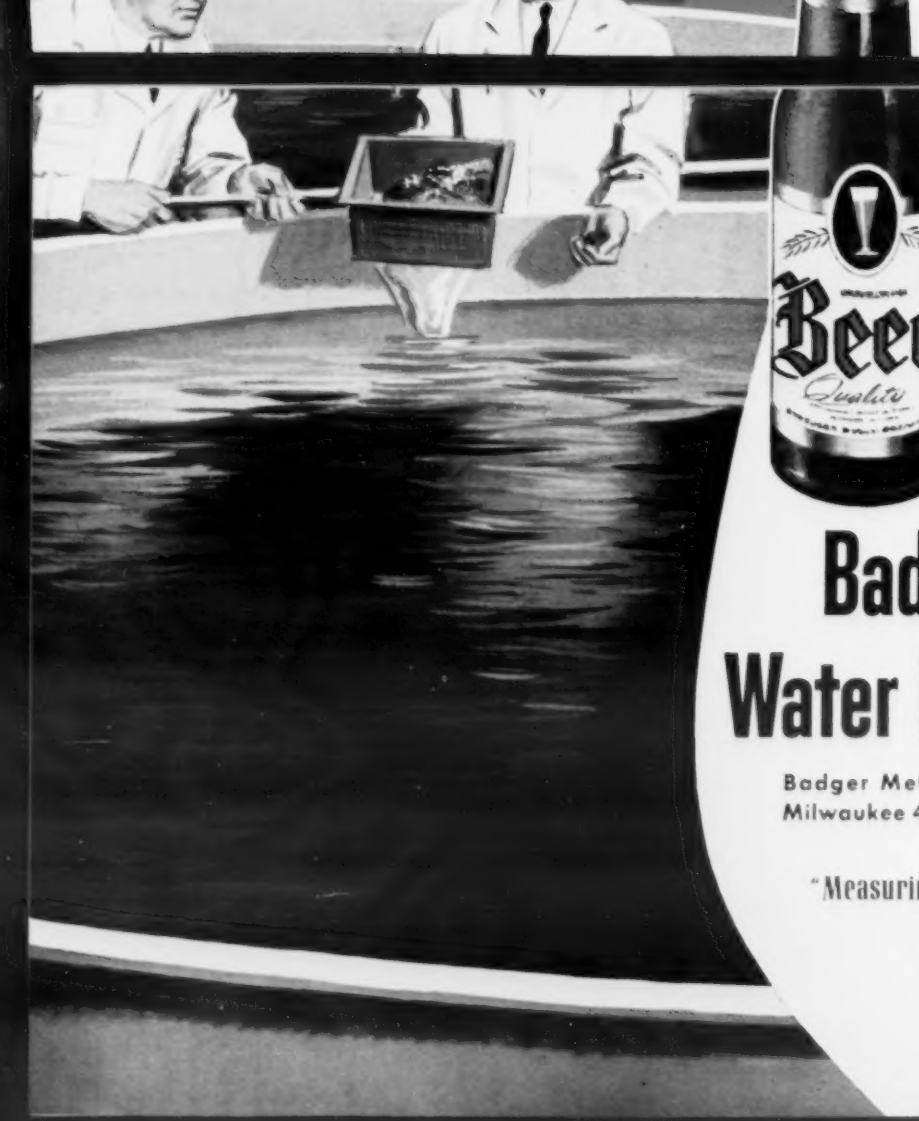

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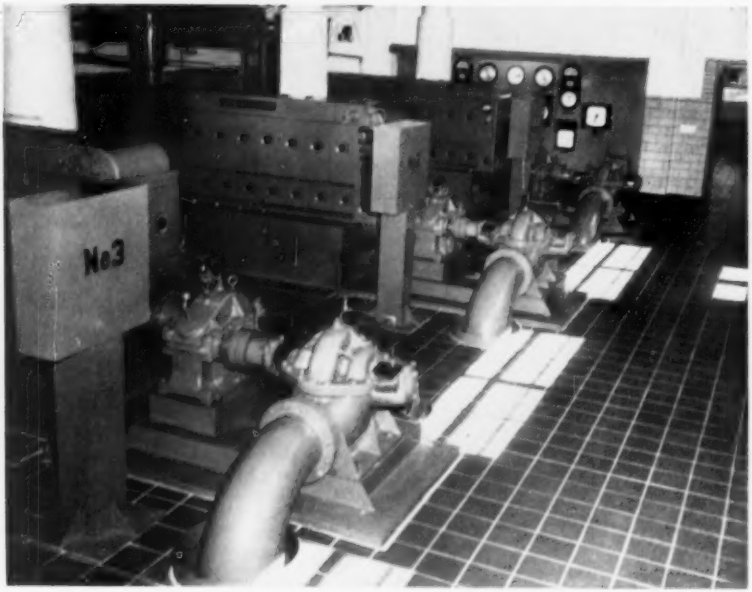

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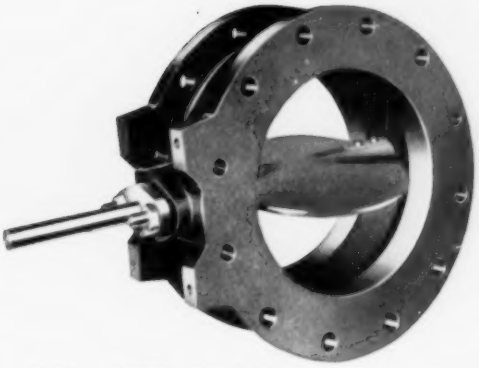

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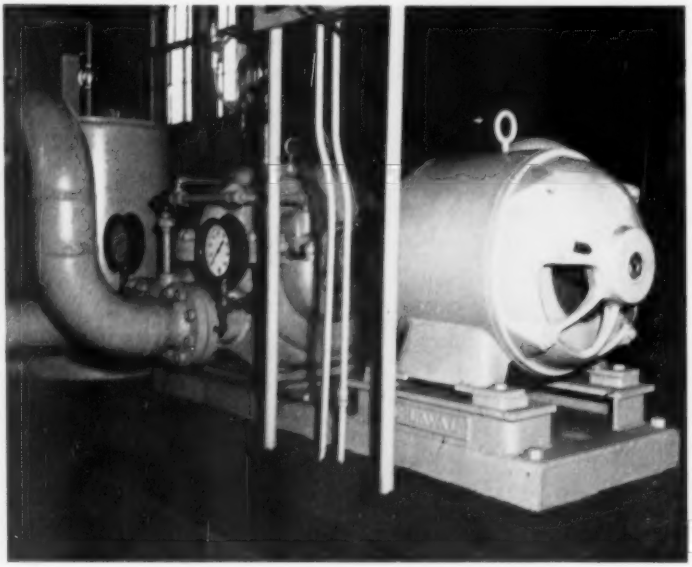

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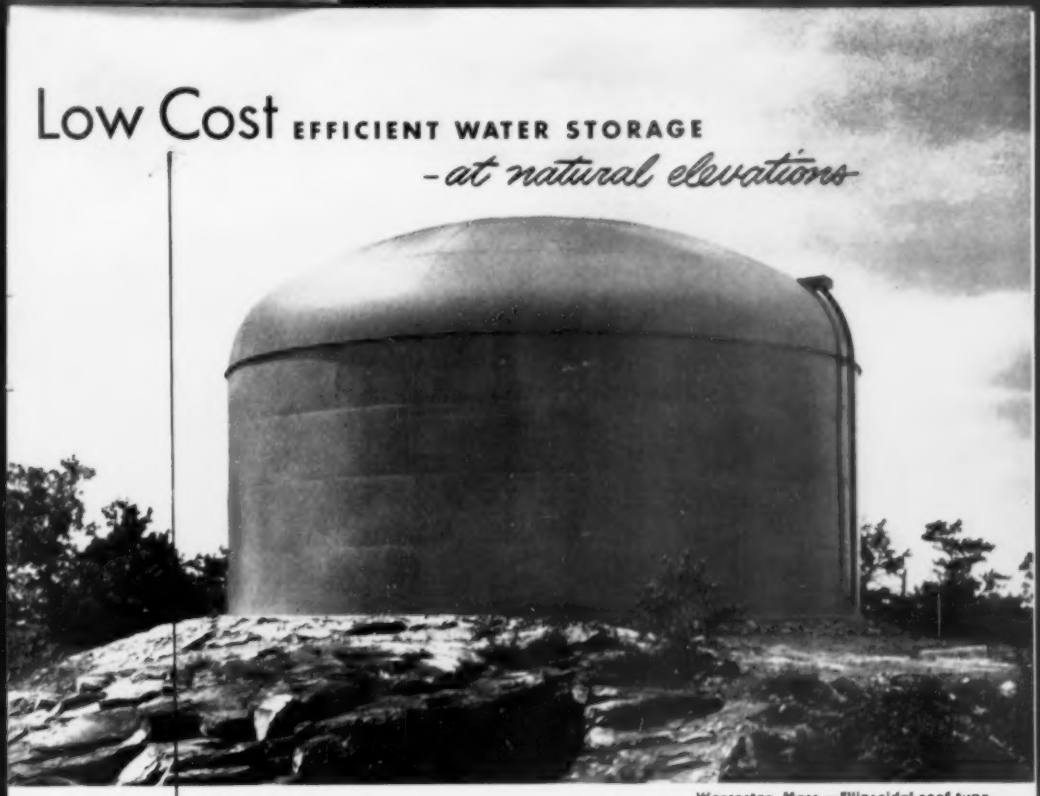

Worcester, Mass.—Ellipsoidal roof type, 1,300,000 gallons capacity.

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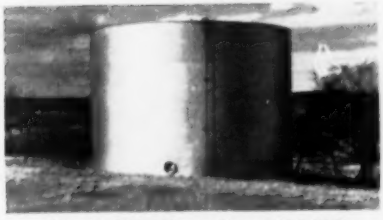
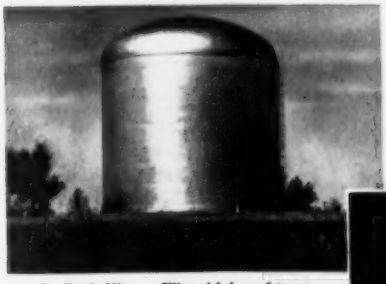


Liberty, N.Y.—Flat roof type, 300,000 gallons capacity.



St. Paul, Minn.—Ellipsoidal roof type, 2,000,000 gallons capacity.

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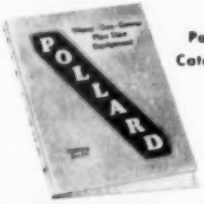

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Table of Contents

PAGE

Operating Experience with Chlorine Dioxide
By Joseph C. Derby 231

Obstacles Encountered at Plants of Bristol County Water Company during Hurricanes "Carol" and "Edna"
By Fred P. Stradling 236

Hurricane Experiences, 1954
By Paul T. Anderson 255

Chlorination Experiences during the 1954 Hurricanes
By Thomas J. Rinaldo 264

Improvements to the New Bedford Water System
By Howard C. Mandell 269

Mechanical-Joint Cast-Iron Pipe
By Thomas F. Wolfe 278

Diatomaceous Earth Filtration
By Henry N. Armbrust 287

New and Interesting Features in Relation to Gravel-Packed Wells and Pumping Plants at Provincetown and Centerville-Osterville, Mass.
By Paul F. Howard 301

New Asphalt-Lined Reservoir for Rutland, Vermont
By Edward L. Tracy 314

Maintenance of Steel Water-Works Tanks
By George A. Sampson 323

The Superintendents' Problems in the Maintenance of Steel Water-Works Tanks
By Allen M. Symonds 331

Tank-Paint Manufacturers' Problems in the Maintenance of Steel Water-Works Tanks
By Charles J. Gotthardt 337

The Painting Contractors' Problems in the Maintenance of Steel Water-Works Tanks
By Roy O. Leonard 342

Memoir of William Storrie 347

Proceedings:
April 1955 Meeting 349
May 1955 Meeting 350

New England Water Works Association
ORGANIZED 1882

VOL. LXIX SEPTEMBER, 1955 NO. 3

This Association, as a body, is not responsible for the statements or opinions of any of its members

OPERATING EXPERIENCE WITH CHLORINE DIOXIDE

BY JOSEPH C. DERBY*

[*Read May 20, 1954.*]

Lawrence's water system serves a population of 105,000 in an area of 30¾ sq mi with purified Merrimack River water. Its purification plant handles a daily average of 7.3 mil gal by means of rapid-sand filtration preceded by alum coagulation, sedimentation and chlorination. The clear water is prepared "odorwise" for distribution by post-aeration of the Sacramento Cone type, followed by a chlorine-dioxide treatment.

This added chlorine-dioxide treatment began experimentally March 19, 1951. The test plan was to extend the treatment over an exploratory period of a month, with the proviso that if its results improved the palatability of the water, it would be continued further. To provide chlorine dioxide of the necessary concentration, a sodium-chlorite solution of known strength was fed through a metering pump into a reaction chamber, inserted in the discharge line of a chlorinator, where the mixing of the chlorine and chlorite solutions generated chlorine dioxide that was directed though a heavy rubber hose to the point of application. The reaction chamber was a vertical, 4½-in. glass tube, one foot long, filled with unglazed porcelain Rashig rings, reduced at the lower end for the chlorine-solution inlet and similarly at the top for the chlorine-dioxide outlet, with the sodium-chlorite solution fed through a T-inlet at the lower end of the chamber, just above the chlorine entry. The chlorite concentrations were made up in 30-gal solutions, depending upon the number of million gallons of water to be treated during a 24-hour period. For example, at 2 lb per mil gal the 30-gal solution would contain 20 lb of chlorite for a daily treatment of 10 mil gal of water. Such a solution would have a concentration of 80,000 ppm. A chlorinator generally delivers a solu-

*Chief Chemist, Water Filtration Plant, Lawrence, Mass.

tion containing not less than 500 ppm of chlorine with a pH value of 3.5 or less. The chlorine dioxide so generated was applied to the clear water from the purification plant at the suction side of the high-lift pumps, discharging into a 42-mil gal distribution reservoir.

To determine in a practical way the taste and odor differences at the end of the exploratory period, arrangements were made on April 20, 1951, for a testing board of unbiased persons to examine and compare samples of the treated and untreated waters. These persons, comprising seven chemists, members of the Chamber of Commerce, State Department of Public Health personnel, newspaper men, etc., judged the waters in a manner similar to the consumer, by sipping equivalent representative portions of each sample. The result of this consensus of opinion was unanimous agreement on an improved quality of drinking water.

On April 23, 1951, a second chlorine-dioxide treatment was put into effect at the effluent line of the open distribution reservoir. The above method of application was employed and the dosage was prescribed in pounds per day of sodium chlorite and chlorine, in contrast to the conventional pounds per million gallons, because of the indeterminable and varied amounts of water daily consumed.

These two treatments operated in series until April 30, 1953, when a pressure survey of the water-distribution system changed the direction of flow and points of entry of purified water into the pipelines of the city. Formerly all of the consumers' water gravitated from the bottom of the reservoir into the system, while the clear water was continuously applied to the top. Consequently, the first chlorine-dioxide treatment affected the water entering the open reservoir, as the second treatment affected the water delivered to the consumers. Today a portion of the pumped clear water at the first chlorine-dioxide treatment directly enters the distribution system, while the remaining portion of it is applied to the reservoir to gravitate through the common system. The effluent water from this reservoir continues to be treated with chlorine dioxide.

When the entire treatment is examined in terms of dosage and effects produced, some interesting facts become evident. The amounts of chlorine and sodium chlorite used varied from time to time at both points of application. Sometimes one or the other component dis-

agreed by weight with the theoretical ratio of 1 part of chlorine to 3.1 parts of technical sodium chlorite; or the recommended ratio of 1 to 2; and even the preference of 1 to 1. The largest excess of chlorine used in the generation of chlorine dioxide was 9 times more than the theoretical dosage, occurring in December, 1951, when 1 part of chlorine to 0.33 parts of chlorite was used. The ratio nearest to the theoretical amounts occurred in October, 1953, when 1 part of chlorine for 2.2 parts of chlorite was applied. In April of 1952, both treatments were using equal weights of each component—namely, 0.99 lb per mil gal at the pumps and 1.23 lb at the reservoir. This relationship of equal weights has possibilities of an economical and preferential dosage.

The annual change in ratio has been to more chlorite than chlorine at both points of application. The records show that the entire year of 1951 favored chlorine in an average ratio of 1 to 0.59 at the pumps and 1 to 0.33 at the reservoir outlet. In 1952 both pumps and reservoir water received a monthly average proportion of 1 lb of chlorine to 0.8 lb of chlorite. Last year the chlorite dosage increased to 1.21 at the pumps and 1.39 at the reservoir for every pound of chlorine applied.

To summarize the chlorine dosage used in generating chlorine dioxide at Lawrence, the records indicate that there has been a substantial decrease in the amount used since 1951, with a tendency toward a more uniform dosage regardless of the season. The monthly averages for chlorine in 1951 were 4.62 and 2.08 lb per mil gal at the high-lift pumps and reservoir, respectively; in 1952 they were 1.76 and 2.20; and in 1953 they were 2.40 and 1.23 lb per mil gal.

A graph of the amounts of chlorine or sodium chlorite alone used at the reservoir is un-informative, showing no pattern for future treatment or understanding of the past. The treatment at the pumps could graphically indicate that, with small variations in chlorine feed, a lower sodium-chlorite dosage during the warm months and higher dosage during the cold months form the pattern to follow. Numerically the highest dosage of chlorite at the pumps was 3.39 lb per mil gal in October, 1953, and 3.54 in February of 1953 at the reservoir. The lowest dosage was 0.99 lb per mil gal in April, 1952, at the pumps and 0.49 lb in June at the reservoir. The average annual

changes in treatment show an increase in chlorite used and decrease in chlorine, approaching nearer to unity ratio with each succeeding alteration.

Besides producing a more acceptable drinking water, the chlorine-dioxide treatment at Lawrence has effected a greater tolerance for O.T. chlorine residual in the distribution system by the people. Formerly, when the O.T. residual chlorine of 0.25 ppm was reached at the effluent of the reservior, complaints of chlorine odor began. The records show that this effluent line reached a high of 0.45 ppm in 1951, 0.85 ppm in 1952 and 1.00 ppm in 1953. Moreover, since April, 1953, that portion of clear water pumped directly into the distribution system has had 9 months of O.T. residual-chlorine readings of 1.00 ppm or greater, without a single consumer's complaint. These high residuals were obtained with a decrease in the amount of chlorine applied, as noted above. They penetrated farther into the distribution system than ever possible with chlorine alone and they allowed a sufficient chlorine-dioxide treatment, with the continuous safety in drinking water that Lawrence has always enjoyed.

Someone has written that the pH value of the reaction generating chlorine dioxide may be the basis for a better understanding and interpretation of its use in water treatment. To study in an arithmetical way factors related to, or affected by, the pH value, graphs have been drawn of the ratio between chlorine and chlorite used, residual-chlorine readings and pH values from results obtained at both treatment points, namely the high-lift pumps and reservoir. Over the period of three years at Lawrence the relation between the O.T. residual chlorine and pH value followed closely the pattern of reciprocal functions. When monthly averages at the pumps are plotted, with an equal degree change of 0.05 in pH value and residual chlorine, the curves intersect at three points between the pH values of 6.9 and 7.0, with residual-chlorine readings between 0.40 and 0.50 ppm. These points of intersection occur when equal weights of chlorine and chlorite are used.

The reservoir charts plotted in like manner show 5 points of intersection between the pH and ratio curves, 5 points of intersection between the ratio and residual-chlorine curves, and 2 points of intersection between the residual-chlorine and pH curves. Within a 0.1-

degree change the ratio and residual-chlorine curves intersect at 5 points inside the limits of 0.62 to 0.72 parts of sodium chlorite to 1 part of chlorine and 0.12 to 0.22 ppm of residual chlorine.

From these observations it can be deduced that at pH values between 6.8 and 7.0, the O.T. residual chlorine should be one-half of the numerical value for chlorite in ratio to each pound of chlorine used in the generation of chlorine dioxide. Such a condition has been approximated here at Lawrence for treatment curves at the high-lift pumps. The reservoir data are not in agreement with such a decision.

In conclusion, permit me to say I am not here to laud the chlorine-dioxide treatment for water; nor do I intend to expound any new theories explaining its chemical action. Too numerous papers of a prospective nature have been written with the hope of discovering a "miracle drug" for taste and odor control in any or all water supplies. My purpose here is to summarize the factual sequence of events in operating experience with chlorine-dioxide treatment for Lawrence water and invite you to visit our system of water purification in its entirety.

OBSTACLES ENCOUNTERED AT PLANTS OF BRISTOL COUNTY WATER COMPANY DURING HURRICANES "CAROL" AND "EDNA"

BY FRED P. STRADLING*

[*Read November 18, 1954.*]

In order that the reader may be familiar with the various sources of supply of the Bristol County Water Company, Figure 1 is presented, showing our four reservoirs—three of which are in Massachusetts and one at our Warren Station in Warren, Rhode Island—and how these reservoirs are interconnected for taking suction. Water from Swansea Reservoir on the right flows overground into the Kickemuit Reservoir, which adjoins the Warren Station. Water from the Anawan Reservoir also flows overground to the Shad Factory Reservoir, the former being part of the Shad Factory watershed. Water from the Shad Factory Reservoir on the left is pumped through an 18-in. pipeline and may be either discharged into the Kickemuit Reservoir below or pumped directly through the Warren Station by certain valve manipulations and discharged into the sedimentation basin. The elevations of the spillways at the four reservoirs are as follows:

Swansea—66.0	Shad Factory—15.3
Anawan—98.1	Kickemuit—6.3

Figure 2 shows the relationship between the Barrington Station and the Warren Station. The Barrington Station pumps from a well field and, after iron-removal treatment, discharges directly into the Barrington distribution system. With a 12-in. submarine line, 1,000 ft long, across the Warren River either station, in emergency, may pump to one or all of the three towns of Bristol, Warren and Barrington served by this company. However, under normal conditions, the submarine line is closed, and the Barrington Station serves only the town of Barrington and the Warren Station serves the towns of Warren and Bristol.

*Manager, Bristol County Water Co., Bristol, R. I.

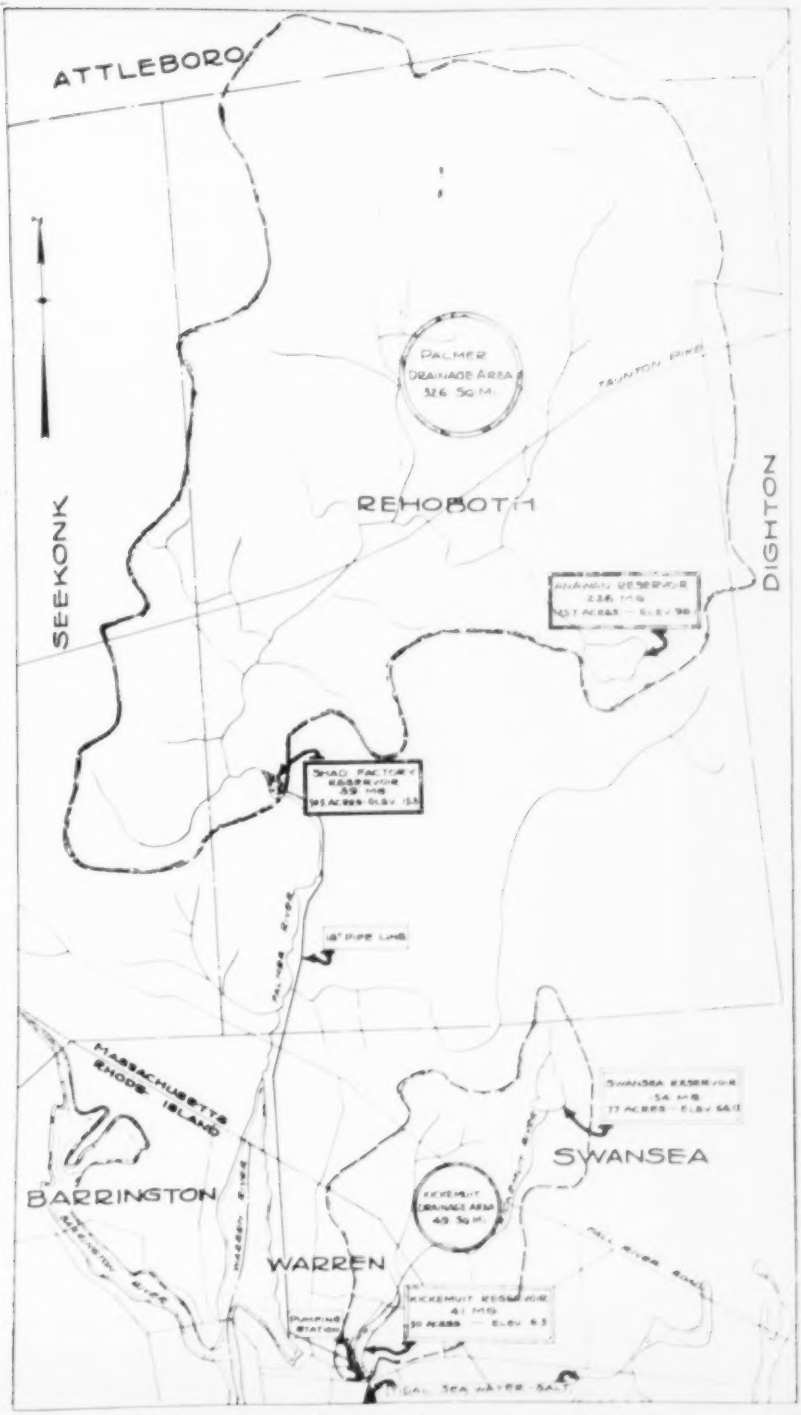

FIG. 1.—SOURCES OF SUPPLY OF BRISTOL COUNTY WATER CO.

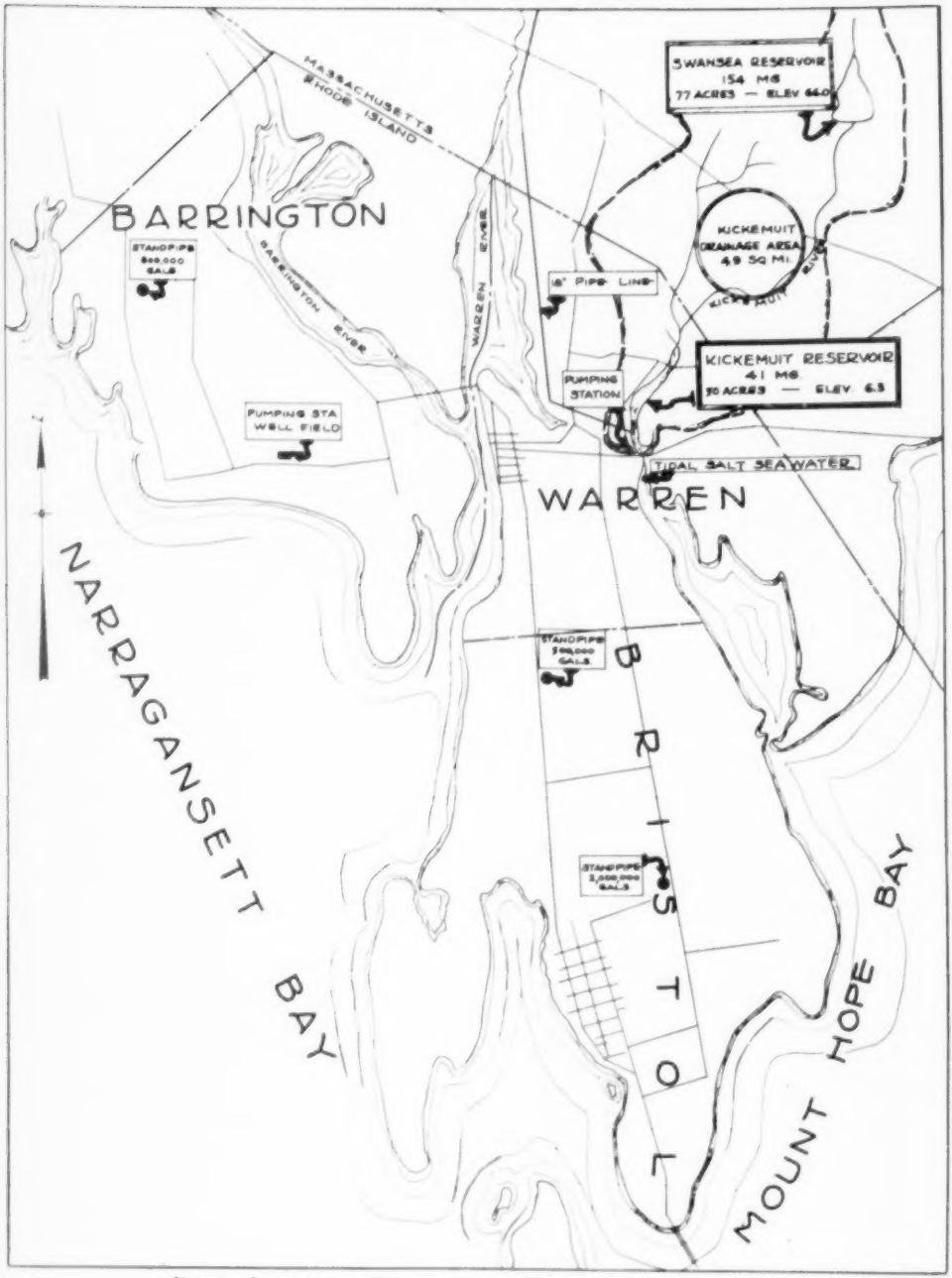

FIG. 2.—LOCATION OF BARRINGTON AND WARREN PUMPING STATIONS.

On Tuesday morning, August 31, 1954, there was no warning that a hurricane was to strike this area by mid-morning. Rain and some wind had been forecast, but the forecasts were not of such character as would warrant the preparation necessary for the hurricane which was to follow.

At 8:00 A.M. we had all three of our distribution-system standpipes full, having an aggregate capacity of 3.3 mil gal, and at this time it was also decided to flush the 12-in. submarine line, which had been closed for many months, so that in case it became necessary to use this line, there would be fresh water to pump in either direction.

At our Shad Factory Station, as well as the Warren Station, we have auxiliary power for pumping both high and low service. We also have in the Warren Station a gasoline-engine-driven generator, which generates sufficient power for our auxiliary motors to operate chemical-feed machines and lights. By 9:00 A.M. our power at the Warren Station became intermittent and only a few minutes later we had a complete outage. At 9:20 A.M. we had a complete outage at the Barrington Station. We had no auxiliary power at the Barrington Station and this station was not energized again until 9:40 A.M., Saturday, September 4—a period of 96 hours—during which period we had absolutely no use of the Barrington Station. The gasoline-engine-driven pumps were immediately started at the Warren Station when electric power failed completely.

By 9:45 A.M. southeasterly winds had increased to approximately 50 mph with a driving rain. By 10:15 A.M. winds had increased to 75 mph and the Kickemuit River level below our reservoir tidal dam was increasing rapidly. At 10:21 A.M. the window at the Warren Station over the generator blew open, with heavy rain coming in on the generator. The window, of course, was closed and bolted down promptly. At 10:22 A.M. a willow tree at the end of our Kickemuit Reservoir spillway was blown down, with southerly winds at this point between 95 and 110 mph. At 10:25 A.M. salt spray from the Kickemuit River was coming over the dam and into our sedimentation basin. High tide was at 10:27 A.M. At 10:30 A.M. men were dispatched to operate the submarine line, but were unable to reach the valves, now under water, with water rising rapidly.

By 10:30 A.M., tidewater began coming in from the Kickemuit

River across the highway into our Kickemuit Reservoir, as shown in Figure 3. Figure 4 shows the Kickemuit Reservoir looking east from the Warren Station after it had been completely salted. In Figure 5 are shown three station operators closing a 16-in. horizontal-geared valve, which changed the discharge from the Shad Factory Reservoir so that it would be discharged directly into the sedimentation basin at the Warren Station. When these men started to operate this valve, they were standing in less than 4 in. of water, and before the valve could be closed, water was up to their shoulders.

Figure 6 shows the tide coming across the highway in front of the Warren Station from right to left, with the Kickemuit Reservoir inside the fence on the left. At this point, the gasoline high-service and low-service pumps were shut down at the Warren Station before taking salt water in the suction from the Kickemuit Reservoir, leaving the entire distribution system on standpipes only. Chloride content at the intake at this point was 90 ppm. By this time, the sewer valve on the inside of the levee at the Warren Station was also closed. By 11 A.M. the tide had come into the Kickemuit Reservoir to a point where the reservoir above the spillway was level with the river below the spillway and water was still rising.

A terra-cotta drain line inside the levee ruptured at this point and our electric pump room began to flood. Two water ejectors and two sump pumps, operating off the plant generator, were placed in service to discharge over the levee, but made little effect on the rising waters in the electric pump room. Telephone service between our Warren Station and Bristol Office, for some unexplained reason, remained intact throughout the period of both hurricanes and at this point a frantic call was made to the Bristol Office for trench pumps, but when the pumps were dispatched to Warren from Bristol, it was impossible to reach Warren because of fallen trees across streets and highways. Men were then dispatched from the Warren Station to the nearest Warren Fire Department station, which responded promptly with a pumper to pump the water from inside the levee and the electric pump room. However, the first pumper did not have long enough hard suction hose, and men were then dispatched to a second Warren Fire Company, which also responded promptly, as shown in Figure 7. The combined lengths of hard suc-

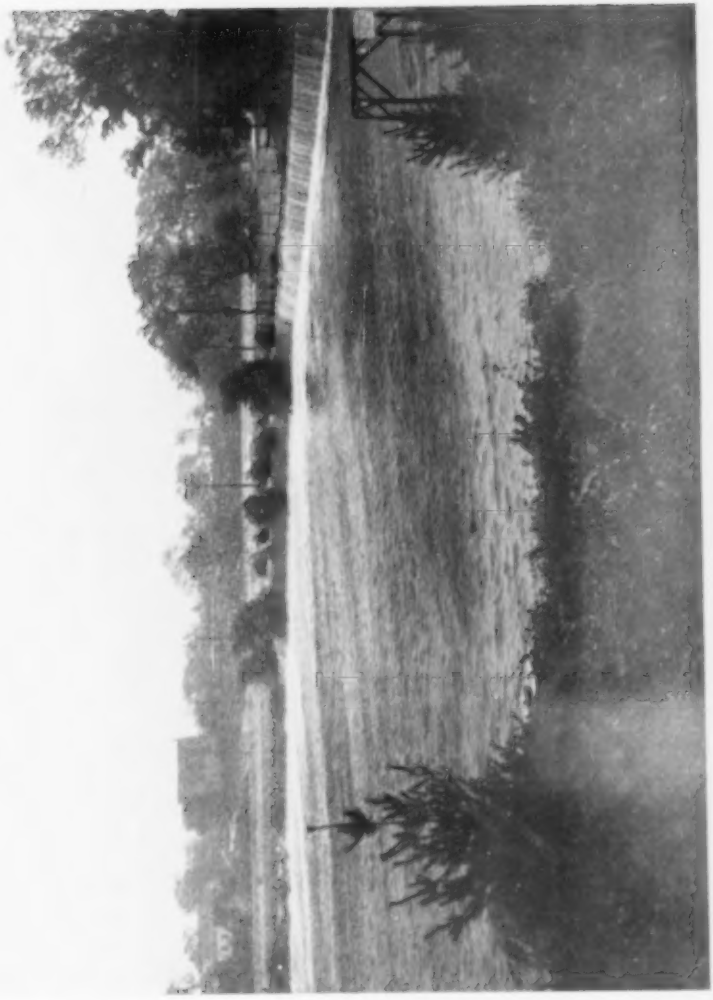

FIG. 1.—TIDAL WAVE STARTS ACROSS HIGHWAY INTO KUKKAMPEE RESERVOIR

Fox Travel Studio

The Towne Studio

FIG. 4.—KICKEMUIT RESERVOIR AT HEIGHT OF HURRICANE (COMPARE ELEVATION OF WATER ON STEEL STRUCTURE OVER INTAKE WITH PREVIOUS PICTURE.)

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FIG. 5.—OPERATING VALVE IN PUMP-STATION YARD

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FIG. 6.—HIGHWAY LOOKING EAST FROM PUMPING STATION. KICKEMUIT RESERVOIR AT LEFT.

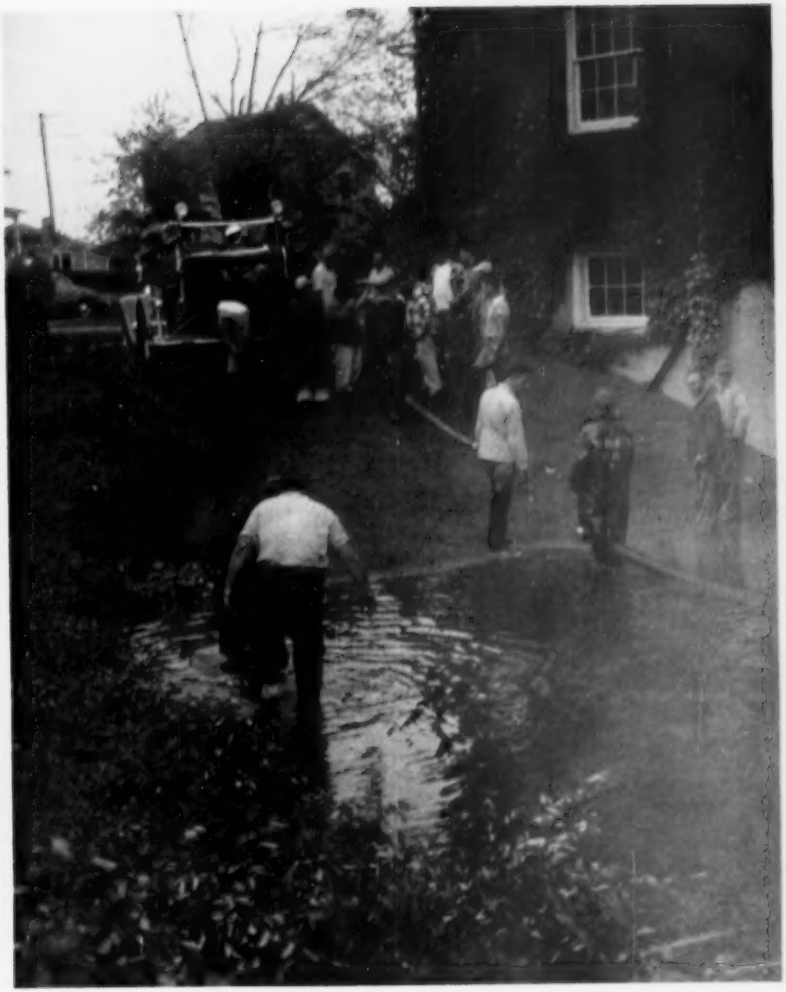

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FIG. 7.—DEWATERING ELECTRIC PUMP ROOM.

tion hose from the two pumpers enabled them to pump the water from inside the levee, after it had reached an elevation in the electric pump room within 3 in. of several large motors, which would soon have been under water.

By 11:45 A.M. hurricane "Carol" was really furious, with winds from 75 to 110 mph and torrential rains. During this hurricane, a total of 3.25 in. of rain fell and water was 5 ft above the tide gates at the reservoir spillway and within 28 in. of the top of one section of the levee around our station.

By 1 P.M. the hurricane was diminishing rapidly and by 2 P.M. water began to recede. Men who had been dispatched to Barrington, to operate the submarine line and man the Barrington Station, were unable to return to Warren because of the flooding of the Barrington and Warren Rivers, and these men finally returned about 3:30 P.M., leaving their trucks in Barrington and walking across flooded bridges.

With hurricane "Carol" now over, the job at hand was to maintain a continuity of service with the Kickemuit Reservoir entirely salted, with chlorides as high as 10,000 ppm near the spillway. A crew of men was dispatched to the Shad Factory Station, to start the gasoline-engine-driven auxiliary pump at this station, and by 6:30 P.M. water from the Shad Factory Station had reached the sedimentation basin at the Warren Station and we were again in operation at the Warren Station by 7 P.M. with a gasoline-engine-driven pump and generator. By 7:30 P.M. our men were able to get to the valves on the submarine line to Barrington, and this line was opened and placed in service, so that we were pumping to all three towns from the Warren Station.

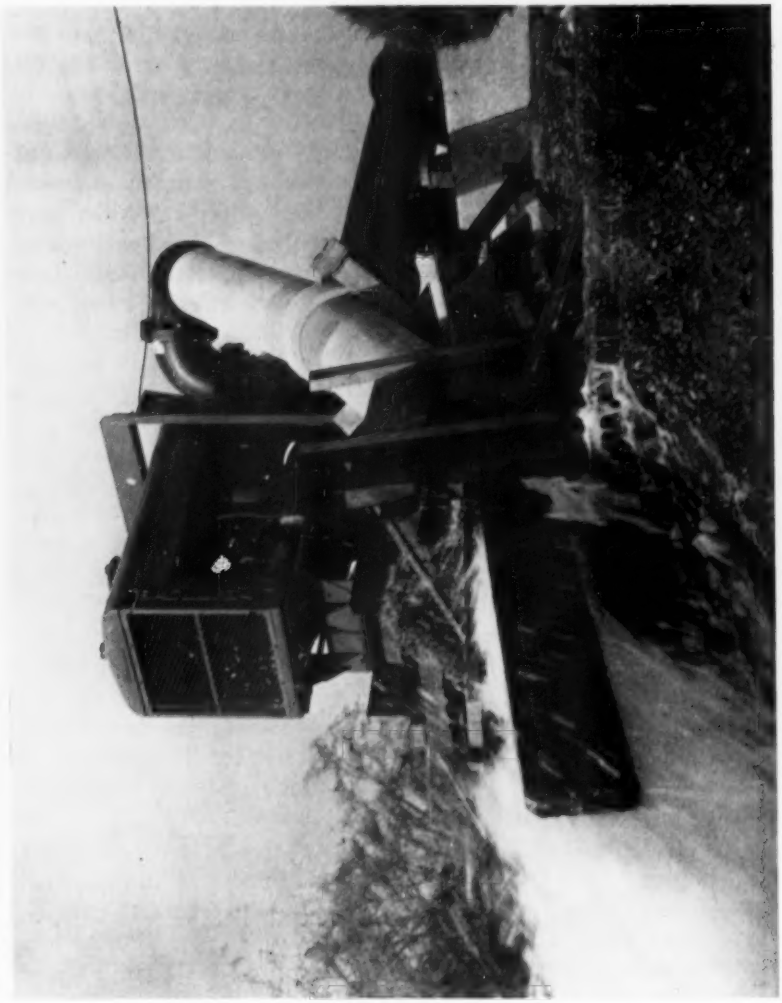
By 9 P.M. martial law had been declared in the three towns and a loud-speaker truck was patrolling the town, saying: "The town is under martial law; get off the street; your water is safe to drink." By 11 P.M. we were able to retrieve our cars and trucks, stranded on the Barrington side of the river, and get them back into the Warren Station.

On Wednesday, September 1, we began the job of cleaning up and what appears now to be an endless job of desalting the Kickemuit Reservoir. The tidewater gates above the spillway are hinged

at the top and weighted on the tidewater-basin side, so that pressure from a high reservoir automatically opens the gates and a high tide automatically closes the gates. The reservoir had been salted for more than a mile above the spillway and it took approximately 48 hours for water from the salted reservoir to flow through the tidewater gates before pumping was actually needed. A great deal of difficulty was encountered in locating heavy-duty contractor's pumps, which could be used for dewatering the reservoir, but three were finally received at 2 P.M. on Thursday, September 2, and were set up and began pumping at 5:45 P.M. These pumps operated continuously until 7 P.M., Friday, September 10, and were stopped at this time, due to the threatening approach of hurricane "Edna".

In addition to the three contractor's pumps received on Thursday afternoon, we also received late Thursday night a 10-in. Marlow pump, driven by a Waukesha gasoline engine, from the Marlow factory in New Jersey, which pump was dispatched to us by truck with police escort over the Connecticut Parkways. This pump was set up on Friday with a 16-in. cast-iron bell-and-spigot suction and is shown in Figure 8. The Marlow pump is a 5-mgd pump and all pumps were operated around the clock until the reservoir was dewatered. Figure 9 shows the reservoir from the highway in front of the station during the course of dewatering, with a boat in the far side of the reservoir, which apparently came over the spillway during the height of the hurricane. The capacity of this reservoir is only 41 mil gal. However, with the tidewater and 3.25 in. of rain on Tuesday, several hundred millions of gallons contributed to flood conditions and large volumes of water in the upper sections of the reservoir carried the chlorides to a point almost beyond comprehension.

On Tuesday, Wednesday and Thursday, we were operating the Shad Factory Reservoir Station and the Warren Station with gasoline-engine-driven pumps, with the usual temporary mechanical failures, which caused delays and loss of water in our standpipes. For several hours Wednesday evening, the rate of flow from the Shad Factory Reservoir seemed to decrease, due to what we thought was an air pocket in the line—this being an 18-in. C.I. pipeline, approximately seven miles long, with portions of it laid in salt marshes along the



The Towne Studio

FIG. 8.—DEWATERING KUSSEMUTT RESERVOIR.

FIG. 9.—VIEW OF RESERVOIR PARTIALLY DEWATERED, SHOWING BOAT WHICH FLOATED IN WITH HURRICANE. *The Tower Studio*

Palmer River, north of the town of Warren. The line was patrolled for breaks on Thursday afternoon, but none were found.

At 8 P.M., Thursday, September 2, our Warren Station was again energized, and the gasoline-engine-driven pumps were taken out of service and electric pumps started. This was after an electric outage of 58½ hours. We were still not energized at the Shad Factory Station, and on Friday, September 3, we had some difficulty with our gasoline-engine-driven pump in the form of a stuck valve in the gasoline motor. This difficulty was eventually worked out, but our pipeline from Shad Factory continued to give us difficulty Thursday through Friday night, and by 5 A.M. Saturday the flow had completely stopped at the Warren Station. We immediately sent men to patrol the line for breaks, and by 7 A.M. the break was found and repaired and the station was back in service at noon Saturday, September 4. During this period of partial and then complete failure of the Shad Factory line, we continued to lose water in our standpipes.

By 9:00 A.M. on Saturday the local power company reached our Barrington Station with repair crews and this station was energized about 9:20 A.M. However, it was found upon starting our equipment that the power was out of phase and all motors were in reverse. The power company re-phased at our transformer bank and we were again on the line at approximately 9:40 A.M., pumping a little more than a 2-mil gal rate at 77 lb pressure. By 1:15 P.M. on Saturday, the Warren Station was again in operation, pumping at a 2.6-mil gal rate at 47 lb pressure, and by Saturday evening the standpipe in Bristol began to fill slowly. This rate of fill continued through Saturday night and Sunday, and by Sunday night, September 5, we were back to normal service with all standpipes filled. During all this time, we were continuing our efforts to dewater the Kickemuit Reservoir and by Sunday at 7 A.M. this reservoir was 36 in. below the spillway. This required the lowering of the 16-in. suction pipe of the new Marlow pump, which was a major operation on Sunday, September 5.

At 10 A.M. on Sunday, we opened two 12-in. drain lines at our Swansea Reservoir, in order to feed fresh water into the upper Kickemuit Reservoir and to some degree flush the salt water down toward the pumps at the spillway. At 3 P.M. on Sunday, the Shad

Factory Station was again energized after 5½ days outage. The gasoline-engine-driven pump was shut down and electric pumps were started promptly. With no further difficulty in delivery to the Warren Station, normal service was maintained continuously thereafter.

Under normal conditions, we do not man the Barrington Station nor the Shad Factory Station, but during this period and until after hurricane "Edna" on September 11, all three stations were manned 24 hours a day. Shortly after this hurricane passed by on August 31, we advised industry that there would be no water for industrial purposes until further notice, and this order continued during the time of our difficulty with the Shad Factory Line through Saturday, September 4. During the same period the factories were also out of power and the restrictions on the use of water made little or no difference to them. On the afternoon of Labor Day, we advised all industry that there would be no further restrictions on the use of water for industrial purposes beginning Tuesday morning, September 7. On Tuesday at 8:30 P.M., an electrical storm caused some difficulty at the Warren Station, with a further electrical outage, and the gasoline high-service pump was started again. The main difficulty seemed to be at our own transformer bank, where the insulators and transformers had been covered with salt spray during the hurricane. With rain on the salted insulators, it made a perfect conductor across the insulators, and we had a very pretty electrical show at our transformer bank, but with little power in the station. The power was turned off back at the sub-station, and the electric company men came back to our plant and found one phase fuse burned, and then washed the entire transformer bank and insulators with water from a fire hose at our station. The line was energized again at 2 A.M. on Wednesday, September 8, with no further interference.

The job now at hand was to continue our efforts to desalt the Kickemuit Reservoir, which seemed to be an endless task. In addition to the high chloride content of our raw water, our color was as high at one time as 360 ppm. However, we were able to turn out an effluent, under strict laboratory control, of 4 to 10 ppm.

By 10:00 P.M. on Friday, September 10, the weather bureau began a very careful warning of the approach of hurricane "Edna". These warnings seemed so real that at midnight, during a heavy rain,

we started to dismantle all of our pumping equipment at the spillway and move our equipment to higher ground, and out of the way of a possible repetition of another hurricane "Carol". Since these hurricanes revolve around an eye in a counterclockwise circular motion, and since the eye of the hurricane "Carol" passed to the west of us, we, of course, received southerly and southeasterly winds. The eye of hurricane "Edna" passed well to the east of us, across Nantucket and the Cape at approximately Orleans, Mass. This reversed the wind direction at our plant, and by 3 P.M. on Saturday the hurricane hit us with northerly winds and with a torrential rain of 4.04 in. in much less than 24 hours. During Friday night, we had made other preparations for hurricane "Edna", which we found later not to have been entirely necessary, but we felt that we were better prepared for any eventuality than we were for hurricane "Carol". Short power outages were experienced during Saturday afternoon and evening, but gave us little trouble. The 4 in. of rain referred to above, with hurricane "Edna" coming in from the north, was a great help in desalting our Kickemuit Reservoir. The pumps at the spillway were not reset and we were still in the process of slowly desalting this reservoir and using a mixture of the water from the Shad Factory Reservoir to dilute the Kickemuit Reservoir water, so that we could take suction partially from the Kickemuit Reservoir. This resulted in an effluent with 15 to 25 ppm chlorides.

The elements apparently were not satisfied with the two hurricanes of August 31 and September 11 which struck this area, and came back on the night of October 15 with hurricane "Hazel". While the eye of this hurricane was some 200 miles west of us, we did have some rather high winds and with high tide at 11:15 P.M., we made certain preparations for coping with any eventuality, at least to some extent. This hurricane passed without any interruption of service and our vigil broke up around 1 A.M. on Saturday, October 16.

The water delivered to the distribution system during the entire period of emergency was maintained at its usual high standard of quality by diverting the source of supply from the Kickemuit Reservoir, which became polluted with salt water at the onset of hurricane "Carol", to the Shad Factory Reservoir, which was not affected by either storm.

During the entire emergency beginning with Tuesday, August 31, the Bristol office was manned on an average of approximately 16 to 20 hours a day for telephone calls. The Bristol office was without power and lights from 9:00 A.M., August 31, until 10:00 A.M., September 8. Bristol Civil Defense authorities took several tank-trucks of water daily from the Bristol office throughout the emergency, including Saturday and Sunday, for delivery to our customers on high ground, as well as people having flooded wells.

During the period of extremely low water in our Bristol standpipe, as set out above, it is estimated that not more than approximately 1,000 customers out of a total of 7,200 in the entire county were without water at any time. All other customers had water at all times. Only those immediately adjacent to the Bristol standpipe, not more than 25 in number, were without water continuously from Wednesday afternoon, September 1, until Saturday evening, September 4.

During the entire period, we had only one distribution-system casualty, and that was when a large tree was uprooted during the height of the hurricane on Tuesday, August 31, and pulled up a 2-in. cast-iron pipeline laid in 1947 with a 4-ft cover. Many hydrants might have been broken by falling trees, but when the debris was all cleared away, we found no such damage.

Considerable thought has been given for many years to some method of preventing the salting of our Kickemuit Reservoir. The force of hurricane "Carol", coming at high tide, however, has proven to us that nothing could have been done to prevent salting this reservoir on August 31. In a recent speech by Professor Smiley, head of the Astronomy Department at Brown University, he is quoted as having said that there might be grave danger in the installation of high levees or dikes to hold back high tides of this character, due to the heavy rainfall which normally accompanies such storms, causing flood conditions of almost equal proportions behind such levees. Professor Smiley further stated that it was his opinion the tides had definite relationship with storms of this type and that he planned further study and research on this matter after retirement from Brown University.

The following quotation is from the United States Weather Bu-

reau Report for August, 1954, at the Hillsgrove Airport Station, Providence: "Hurricane 'Carol' passed rapidly NNE across the state on the 31st, accompanied by heavy rains, and a sustained wind of 90 mph with a peak gust of 105 mph. Nearly all areas along the coast and Narragansett Bay, including downtown Providence, were flooded, with many homes completely demolished, 19 lives lost, and an estimated property damage of over $200,000,000".

Without doubt, the most heartbreaking experience during this emergency was our failure to render continuity of service as outlined above. It was my first such experience in 37 years at various properties of the American Water Works Co. in the East and Middle West. Little sleep was had by our entire staff during the twelve-day period from August 31 through September 11. The loyalty of our supervisors, station operators and outside men was an experience of which to be proud. Experiences encountered during this emergency which taxed the wits of our personnel and seemed at the moment to be insurmountable included, among other things, a spontaneous-combustion fire in our carbon-feed machine at the Warren Station; at 3 A.M., during a heavy rain, a small white dog, which was almost impossible to dislodge, was found trapped insde the retaining wall of the Kickemuit Reservoir; and finding the Barrington Station out of phase when first energized after a 96-hour outage. These were all extracurricular activities in the normal operation of a water-works property, and particularly so during such an emergency.

HURRICANE EXPERIENCES, 1954

BY PAUL T. ANDERSON*

[*Read November 18, 1954.*]

Hurricanes occur most frequently in August and September, the complete range being from May to October, with very few hurricanes occurring in May and June. Storms of the hurricane type have their origin in the Caribbean Sea in an area referred to by seafaring men as "The Doldrums". In this area there is no horizontal movement of air and warm air at the surface of the sea begins to rise, since it is lighter than the cooler air above. As it rises, it begins to rotate in a counter-clockwise direction, having at the same time a slow lateral movement toward the west, caused by the westerly trade winds. Since the general movement of air masses across North America is from west to east, these two conflicting forces cause the storm to head in a more northerly direction. The usual path of such tropical storms is northerly off the coast of Florida and thence northeasterly off Cape Hatteras, usually missing New England by a safe margin. Because of the development of various high-pressure and low-pressure areas in the vicinity of New England, there are occasions when the storm may be drawn into a low-pressure trough and pass directly over parts of New England. As the storm begins, its velocity is very slow—about 10 miles per hour. Its velocity of rotation, however, rapidly increases until it is often as high as 100 miles per hour or more. As the storm moves northward and passes Cape Hatteras, its velocity laterally may increase to 60 mph or more. Storms of this nature almost always pile up a wave over the ocean, created by the force of the wind and rolling water. As long as the storm remains off the coast it results only in high seas, but as the storm approaches the shore, water piles up on shallow flats and in small bays and harbors. Thus, a moderately small wave may be intensified into a very high wave as the bays narrow inland. Such storms are usually accompanied by heavy rain,

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usually greatest near the center of the storm path. Such a storm was "Hurricane Carol".

When looking into the matter of tropical storms for New England one wonders why we are so unprepared and surprised when we do get one. As far back as 1635 there is a record of a very severe storm in August of that year that caused a 20-ft. tide at Boston twice in 12 hours and sent the Narragansett Indians scurrying into the trees for their very lives. In 1748 there was a tornado at Pepperell, Mass., and another at Leicester, Mass., in 1759. On October 20, 1770, there was a storm whose description fits that of the recent hurricanes. Again in 1773 there was a hurricane on the Merrimack River, causing damage at Haverhill, Salisbury and Amesbury. Only 9 years later, on June 23, 1782, there was a severe tornado in Western Massachusetts and Southern Vermont. On August 23, 1786, there was a hurricane that struck Sturbridge and Southbridge. On August 15, 1787, the very next year, there was a very severe storm in Massachusetts with heavy rain and wind. Again, only one year later, on August 19, 1788, there was a very severe hurricane that struck all of New England, knocking down trees and causing extremely high tides. Skipping 16 years to 1804, we find that there was a very bad storm with snow and rain that caused much damage to trees, vessels, etc. On September 23, 1815, there was a hurricane, the description of which fits the pattern we have recently grown used to. This one caused high tides and tree damage, and blew the roofs off houses. On October 2, 1841, the records show another storm causing tides and damage, mostly to Cape Cod. Again, on October 17, 1849, there occurred another cyclonic storm with the usual high tides, strong winds and tree damage. Only 2 years later, on August 22, 1851, there was a tornado that caused damage in the Worcester area and in the Arlington area. On September 8, 1869, there was a recorded hurricane with the usual damage to wires, boats, houses and trees.

Beginning in 1873 there are records at the Boston Weather Bureau, with wind velocities and more specific data. On September 26, 1888, there was a tropical storm that moved from Florida to New England in 24 hours, with 47-mph winds at Boston and 56-mph winds at Woods Hole. In 1890 there was what seemed to be a localized storm that blew off roofs in Lawrence, Mass. On October 13, 1891, a

storm is recorded with winds of 30 mph at Boston and 48 mph at Woods Hole. In August of 1893 there were three storms with winds as high as 59 mph at Blue Hill. Again in the same year, in October, a storm indicated 39 mph at Boston and 58 mph at Blue Hill.

In October of 1896 a storm is recorded, with the usual tides, etc., and with wind gusts up to 84 mph at Block Island, with 40 mph at Boston and 46 mph at Blue Hill. Two years later the so-called "Portland Storm" wrecked 300 vessels, causing $2,500,000 marine damage. Boston recorded winds of 47 mph and Blue Hill 58 mph. Again in only 3 years, in 1901, a northeast gale caused winds of 47 mph at Boston. In 1904 there were three storms, one each in September, October and November. Winds of 64 and 65 mph were recorded at Blue Hill. There were two storms of hurricane type in November of 1907, with winds up to 53 mph at Blue Hill. The interval between storms spreads now to 10 years, to October 30, 1917, when Blue Hill recorded 65 mph. Seven years later, in August of 1924, a tropical storm caused winds of 62 mph at Blue Hill and 4.37 in. of rain fell on Boston. Only three years later, in August of 1927, a hurricane passed 100 miles east of Nantucket, causing winds of 53 mph at Nantucket.

Most of us are quite familiar with the storm of September 21, 1938, which caused winds of 73 mph at Boston and 87 mph at Providence and did such extensive wind and water damage. The hurricane of 1944 found some of us away from New England traveling at Government expense, but it falls into the general pattern with all the others. Checking the Weather Bureau records in Boston since 1873, we find that the interval between tropical storms that have hit New England varies from only one year to a maximum of eleven years, with an average incidence of only 4.4 years between storms.

Coming back to 1954 and our most recent tropical storms, we found that the morning of August 31, 1954, dawned wet and miserable, as had so many other mornings this exceedingly wet year. Rainfall records for New Bedford show that we had 5.04 more inches of rainfall for August and September alone than the normal for these two months. Probably most of us listened to several weather reports before leaving for work that morning, none of which was very alarming. However, the mention in the same breath of heavy rain, high winds and high tide undoubtedly brought memories of 1938 back to

those who had experienced that "unnamed" hurricane. The thought of southeast winds pushing high tides into the narrowing funnels of Narragansett and Buzzards Bays should have been cause enough for alarm. But, with the weather forecasts being played down, most of us allowed thoughts of danger to slip to the back of our minds, figuring that at worst this was going to be another miserable day and a good time to get caught up on the paper work.

The recently re-organized Southeastern Health District of the Massachusetts Department of Public Health includes 109 cities and towns and stretches from Framingham to Provincetown and the Islands. The engineering office for the District is now located at the Lakeville State Sanatorium, about two miles from the center of Middleborough. This Department's cars are *not* two-way radio-equipped; no radio was playing in the office, and the loss of AC current and telephone service did not occur until about 10 a.m. Since this state institution generates its own DC electricity, the lights in the office did not go out and work went on as usual. About 10 a.m. the falling trees around the office made it necessary to move some of the cars to safe locations, and we then realized with concern and alarm that we were really getting the full brunt of the hurricane. Much of the staff is from the city of New Bedford and vicinity, and concern for families and friends made several want to start for home immediately. The arrival of Gil Joly, Assistant Sanitary Engineer, from New Bedford at this moment, with his tale of having to go over lawns and around trees with branches, shingles, roofs and trees falling like rain around him, made a decision to sit tight the only sensible one.

With the telephone out, contact with the central office in Boston and the rest of the outside world was impossible. The Region 8 Civil Defense Command Post is located at the Lakeville State Sanatorium, with a State Police radio set and a "ham" radio set as part of its equipment. We immediately went over there to see if we could get in touch with Boston, and found the place locked and no one about. Failing in this, we returned to the office and finally got a small radio to play on DC current. We listened to many wild and woolly tales and reports, and began to realize that we had a job ahead of us just finding out the condition of the many public water supplies. We also needed to know what had to be done to protect the consumers and help the various water departments.

Early the next morning the central office dispatched four men to help us and we spread out over the district to determine what had happened to the public water supplies. Once a man was dispatched on a route there was no way to get in touch with him until he returned. This lack of ready communication made a quick survey impossible. We had no way of knowing how many water-supply sources had been inundated and how many breaks in mains had occurred. As we went along, we found that all the water departments were doing a superb job, the men working without regard to hours or fatigue.

An early examination of the Buzzards Bay Water District showed that there had been no danger to the source, but that at least one serious main break had occurred. Consequently a boil order was issued as a precaution until the results of bacterial samples were known. The samples showed that the water in this system was free from contamination and the boil order was withdrawn.

Again in the Wareham Fire and Water District there was no danger to the source, but a serious fire in a department store on the flooded main street caused a heavy draft of water to fight the fire and pressure was lowered considerably. Fortunately a positive pressure was maintained at all times and there was no contamination of the water supply. Firemen had to fight this fire in water up to their armpits and from boats.

With the coöperation of the State Police Radio and the Barnstable County Police Radio and by personal visits, we were able to get reports from all the water departments along the coast that we feared might have suffered major damage. These reports showed that lower Cape Cod got off lightly with no sources flooded and damage held primarily to lost meters, damaged services, damaged hydrants and uncovered mains. It is interesting to note that one water department had a newly laid asbestos-cement main pop out of its trench and float. As a routine matter each representative of the Department collected a bacterial sample from each water supply visited. The negative results were most satisfactory.

A tabulation of damage estimates for the Cape Cod and Buzzards Bay areas follows:

Bourne Water District	meters and services	$11,000
Buzzards Bay Water District	mains, meters, services	3,100
Dennis Water District	services and meters	2,000
Fairhaven (town)	mains	3,000
Fairhaven Water Co.	mains and meters	14,700
Falmouth	mains on bridges, meters, exposed piping, new mains	16,000
Marion	mains, hydrants, pumping station	6,500
Mattapoisett	hydrants, meters, services	5,600
New Bedford	distribution system, watershed	15,000
Wareham Water District	mains, hydrants	25,000
	Total for Cape and Buzzards Bay	$101,900

The water supplies on the islands were not so fortunate as those on nearby Cape Cod. On Martha's Vineyard the Edgartown Water Co. escaped unscathed, but the Lake Tashmoo Pumping Station of the Tisbury Water Department was flooded, as were the pump well and the lower two lagoons of the Oak Bluffs supply. Tisbury was indeed fortunate to have its new, 220-ft, 1,000-gpm gravel-packed well at a ground elevation of about 115 ft above mean sea level. This well with its gasoline auxiliary engine easily handled the town's demands during the emergency period.

The tidal wave of "Hurricane Carol" breached the dike separating the lower lagoon at the Oak Bluffs source from actual salt water. The same tidal wave inundated the lower of the two concrete basins and flowed into the pump well itself, making it necessary to shut down the pumping station. A combination of fortunate circumstances made it possible to return this source to service without endangering the town of Oak Bluffs. First of all, there was no fire during this time; second, there was no damage to the pumping station itself; third, this supply is chlorinated at all times anyway; and fourth, water flows by gravity from the upper concrete basin through the pump well, wasting to the lower lagoon 24 hours per day. The dilution afforded by this constant flow of water reduced the chlorides in the well to the point where they were not noticeable when pumping was resumed.

Neither the Wannacomet Water Co., serving the populated center of Nantucket, nor the Nantucket municipal supply, serving Siasconset, suffered any major damage.

The damage summary for the islands shows $10,000 for Tisbury and about $500 each for Oak Bluffs and Nantucket, making a total of $11,000.

In the Narragansett Bay region damage was limited to Fall River, Somerset and Swansea. Principal damge at Fall River was to trees on the watershed of North Watuppa Pond, estimated at $40,000. The Pierce Lane gravel-packed well of the Somerset Water Department was flooded and Swansea lost services, meters, curb boxes and hydrants.

Somerset was in a bad way, due to a lack of auxiliary power at the three new gravel-packed wells in South Dighton and a mechanical failure at its all-but-abandoned tubular well field. Swansea was able to give some water to Somerset through a permanent interconnection and Fall Fiver aided with fire hoses across the Brightman Street Bridge. Somerset did help itself by getting the old well field going and hiring a diesel engine and pump during the emergency. The need for adequate auxiliary power to carry on in the event of the loss of electricity cannot be emphasized too strongly.

A tabulation of damage for the Narragansett Bay Region follows:

Fall River—Diesel control panels, transformers and switches	$ 3,500
Labor for tree damage	40,000
Somerset—Rental of pump	100
Fuel for diesel and labor	1,000
Flooded Pierce Lane Station	7,000
Well-field damage and other	2,900
Swansea—Services, hydrants, meters, curb boxes	10,000
Total for Narragansett bay	$64,500

In the South Shore area Cohasset, Scituate and Marshfield suffered damage. Loss of electricity and lack of sufficient auxiliary power made for a serious situation in Cohasset. Added to this, Tom Culliney, Cohasset Superintendent, suffered burns on both hands from a rented auxiliary gasoline engine and had to be hospitalized. "Teke" Sherman of Scituate lent Tom a helping hand during his hospitalization. The situation at Scituate was uncomfortable, because of loss of electric power without complete standby motive power at each of the

seven pumping stations. Fortunately, a successful pumping test had just been completed on a new well, and this new well was pressed into emergency service with a rented pump and engine. Marshfield's damage was mainly wind damage to the roof of the Water Department shop. A tabulation of estimated damage for the South Shore region follows:

Cohasset—Water mains	$5,000
Scituate—Rental of diesel engine	750
Marshfield—Roof of Water Dept. shop	850
Total for South Shore	$6,600

In the northern sections of Plymouth and Bristol counties, damage was reported from Attleboro, one water district in Easton, Taunton, and Abington-Rockland's source in Pembroke. A tabulation of estimated damage for this region follows:

Attleboro—Well controls	$ 500
Easton—Unionville Water Dist.—Hydrants	1,500
Taunton—Assawompsett Pumping Station	50
Elders Pond screen	50
Causeway at Assawompsett	500
Electric motor at Assawompsett	900
Watershed cleanup	10,000
	$11,500
Abington-Rockland—Buildings and trees	500
Total for Northern Bristol and Plymouth Counties	$14,000

Slight amounts of damage were reported from Norfolk, Middlesex and Essex Counties, amounting to not over $15,000.

A total damage estimate of $213,000 has now been reported. Some of the estimates are high and some are low, but it is safe to say that the damage from "Hurricane Carol" alone, to public water supplies alone, amounts close to one-quarter million dollars. It will be noted from the figures given that almost one-half of the damage occurred in the Buzzards Bay area.

In addition to damage to water supplies in southeastern Massachusetts, the tidal wave with "Hurricane Carol" caused an estimated

$150,000 damage to sewage-treatment plants and sewerage systems in Fall River, Marion, Falmouth, New Bedford and Nantucket.

A great many private water supplies were flooded in the Buzzards Bay and Mount Hope Bay areas, and the water was made unsafe for drinking. These wells are being examined at the request of the local Boards of Health and, where feasible, are being pumped out and disinfected. Many will have to be abandoned because of the serious pollution. So far, nearly 200 of these wells have been examined through this office alone.

Adding insult to injury, "Hurricane Edna" came along soon after "Carol" with all her ballyhoo and minute-to-minute bulletins. "Edna" probably frightened more people than did "Carol", but the resultant damage consisted mainly in recurring losses of electric power and telephone communication. Had the storm arrived at flood tide, it could have been just as destructive as its predecessor. Rainfall with the second hurricane began about 7 a.m. and in some places amounted to 8 in. or more in 10 hours. This heavy rain, falling on ground well saturated as a result of the rain with "Hurricane Carol", caused a great deal of local flooding. Storm-drainage systems were overtaxed and streets and basements were flooded. Rivers overflowed their banks, flooding well fields of several public water supplies.

We have all learned some lessons from these storms that will stand us in good stead when we face up to the fact that we can expect hurricanes with some degree of regularity. These same lessons are applicable to situations that may be caused by enemy action, as well as the forces of nature. The author believes that it is prudent for water- and sewage-works officials to make provisions to meet such emergencies, with particular attention to the following:

1. Provide auxiliary gasoline- or diesel-engine power, with or without generators, to serve moters usually used.
2. Take steps to exclude tide-water and river-water overflows from entering pumping stations.
3. With the approach of hurricanes, fill all elevated tanks and standpipes to resist excessive wind velocities.
4. Organize and train auxiliary personnel to stand by and assist during emergencies.

CHLORINATION EXPERIENCES DURING THE 1954 HURRICANES

BY THOMAS J. RINALDO*

[*Read November 18, 1954.*]

The experiences presented in this paper are concerned with the problem of maintaining in effective operation the chlorination program of the Water Division of the Metropolitan District Commission during the recent hurricanes. This water supply, which serves approximately 27 cities and towns in the Metropolitan District and vicinity with approximately 200 mgd of water, is spread over a rather extensive area. Therefore, it is necessary to operate treatment plants at many widely scattered points. The amounts of chemicals used daily at these treatment stations vary from approximately two pounds per day at a small installation in Stoneham to approximately 2,000 lb of chlorine and 500 lb of ammonia per day at the Norumbega Reservoir in Weston. Such wide variations in rate of application make it necessary to provide various types of stand-by equipment for emergency use.

In order that there may be a better understanding of the system, it might be well at this time to locate and describe briefly the chlorinating plants under consideration. The two principal aqueducts carrying water into the District are the Hultman Aqueduct and the Weston Aqueduct, both of which have chlorinating stations in Weston, a few miles west of Boston proper. At the Norumbega Reservoir on the Hultman Aqueduct, two Wallace & Tiernan air-operated master chlorinators and two hydraulically operated master ammoniators are in use. During early September, 1954, approximately 1,300 lb of chlorine and 260 lb of ammonia were used daily to treat a flow of approximately 140 to 150 mgd. At the Weston Reservoir on the Weston Aqueduct, two Builders Iron Foundry chlorinizers and two dry-feed ammoniators are in use. During the same period, approximately

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400 lb of chlorine and 80 lb of ammonia were used daily to treat a flow of approximately 40 to 50 mgd. Since both of these treatment stations, as well as most of the smaller ones, are located above the hydraulic gradient, it is necessary to have pumps in operation to provide water under pressure for the operation of the treatment equipment. Air compressors are also in use at both stations to operate principal and accessory equipment.

At various points in the distribution system, there are also smaller reservoirs which "ride on the line", so to speak, and at each of these points a chlorinating plant is in operation, to insure that no water leaves any open reservoir without being treated with chlorine. At Waban Hill Reservoir in Newton, just west of Boston, a chlorinator is operated by water under pressure from the city of Newton lines, and during the two hurricane emergencies, this plant continued to function normally, since no electrical power was needed for its operation.

North of the city of Boston, in Stoneham, there are three chlorinating stations, located at the Spot Pond pumping station, Fells Reservoir and Bear Hill Reservoir. The Spot Pond treatment plant was not affected by the hurricane emergency, since water under pressure was supplied to the treatment equipment from the pumping station.

The latest addition to the system of outlying reservoirs is in the Blue Hills, south of Boston, where the Blue Hills Reservoir is located. This reservoir is also equipped with a chlorinating station to treat water passing out of the reservoir. With the exception of the Spot Pond treatment plant, all of the chlorinating stations described are automatically controlled to feed chlorine at any predetermined rate.

When hurricane "Carol" struck on August 31, all treatment plants had to be put on an emergency basis, with the exception of those at Waban Hill Reservoir and Spot Pond. At the two principal treatment plants, at Norumbega Reservoir and Weston Reservoir, the initial switchover to emergency power was automatic. At Norumbega Reservoir, when the municipal power failed, a 7½-kva Readypower generator unit automatically "kicked in" and took over the job of providing power for the operation of the electric water pumps and air compressor. At the Weston Reservoir treatment plant, a 5-hp gasoline-engine-driven water pump took over the task of providing water under

pressure for the chlorinating equipment. With no electricity to operate the air compressor, the air pressure dropped to a predetermined level, at which time a tank of compressed carbon dioxide took over the job of providing the small volume of air substitute needed to operate the treatment equipment. Additional emergency equipment was quickly moved to the principal chlorinating stations to act as standby equipment.

Personnel of the sanitary section were soon on their way to the other treatment stations where power had been cut off. Arrangements were made with the Spot Pond pumping station to maintain a pumping rate that would prevent any water from being drawn from the Fells or Bear Hill Reservoirs until emergency chlorination equipment could be moved in. Fallen trees made it impossible to get to these two stations except by personnel on foot, but within a short time, portable chlorinating equipment which did not require water under pressure was installed and operating. At Fells Reservoir, a portable dry-feed chlorinator was installed, with the chlorine gas introduced into the water through a diffusor at the end of a silver discharge tube at the rate of approximately 12 lb per day. This equipment could feed chlorine at rates up to 300 lb of chlorine per day. At Bear Hill Reservoir, a carboy of diluted sodium-hypochlorite solution was set up with a siphon tube containing a constant orifice. By carefully regulating the flow, a daily application of approximately two pounds of chlorine was made. A similar set-up was used at Blue Hills Reservoir, in the form of a 20-gal crock with a hose clamp on the discharge hose, to regulate the flow to provide for a daily dosage of approximately 12 to 15 lb of chlorine per day.

In order to provide for stand-by equipment at the principal chlorinating plant at Norumbega Reservoir, a trailer-mounted OCD (Office of Civilian Defense) gasoline-engine-driven pump was set up for possible use. Strangely enough, no sooner had the last connection been made on the discharge hose of the unit than the gasoline-engine-driven generator "quit". Within a moment or two, the pump was started and the water pressure was maintained to the treatment equipment. However, with no electric power to operate the air compressor, another emergency standby "set-up" was called into play. A bank of three carbon-dioxide tanks is connected through a manifold

to the air line supplying air to the treatment units. As the air pressure dropped to a value set on the regulating valves, the valves opened and a stream of carbon-dioxide gas took over the task of providing an air substitute. Since a rather appreciable volume of air per unit time was necessary to operate the chlorinators, it was found necessary to have at least two cylinders of carbon dioxide in operation at the same time, to prevent chilling of the lines and loss of pressure due to the rapid rate of use. After the necessary repairs were made to the generator unit, it was put back into service, and the OCD water-pump unit shut down. These units continued to be used for the first few days. When it became evident that the restoration of municipal electric power was at least several days away, another step was taken. A powerful 25-kw generator unit, which had been purchased to replace the single-phase equipment that had been outgrown, was set up temporarily and a new, three-phase, 7½-hp electric motor was installed on one of the water pumps, to operate from the power provided by the new generator. This "set-up" continued in operation night and day for the remainder of the emergency when, on Sunday, September 5, the municipal power was restored.

An additional piece of equipment, which was kept standing by, but was not used during the emergency, is a trailer-mounted solution-feed chlorinator with a gasoline-engine-driven pump as part of the equipment. This trailer chlorinator is completely self-contained, with two 150-lb cylinders of liquid chlorine mounted within the body of the trailer. The rate of chlorine feed with this machine can be adjusted to any value up to approximately 300 lb per day. With this unit, chlorine could be applied to an open well or to a pipeline under pressure through a silver discharge tube, fitted through an appropriate corporation cock.

On Friday, September 10, it became increasingly evident that hurricane "Edna" would probably visit the area on the next day. Accordingly, preparations were made in advance and the automatic chlorinators at the outlying stations in Stoneham, north of Boston, and the Blue Hills, south of the city, were shut down after the stand-by emergency equipment was put into operation. This work was done during the night of September 10 and the morning of September 11. During the afternoon of September 11, the edge of hurricane "Edna"

moved through this area, again cutting off the municipal electric power serving the two principal treatment plants and the three outlying stations. This time, however, all preparations were completed in advance and the standby generators, pumps and chlorinators took up their appointed tasks without mishap. In spite of the widespread damage to power lines for a second time within two weeks, municipal power was rapidly restored and by the morning of September 14, full operation under normal conditions was again the order of the day.

Before concluding, it might be well to make some observations concerning the quality of the water being treated. An examination of the laboratory records showed that during the period between the two hurricanes, the raw water at the principal chlorinating plants at Weston met the bacteriological standards of the U. S. Public Health Service for a drinking-water supply before being chlorinated. Samples collected on September 7 showed the following results in part . . . at Norumbega Reservoir, the raw water had a 37°C. plate count of 28 bacteria per ml, with one 10-ml lactose tube positive out of five tubes . . . at Weston Reservoir, the raw water had a 37°C. plate count of 70 bacteria per ml, with one 10-ml lactose tube positive out of five tubes. In spite of the generally acceptable quality of the raw water, it has been the policy of the sanitary section to maintain continuous chlorination of all water at all times, not only to insure that all bacteria of sanitary significance are destroyed in the raw water, but also to provide a chlorine residual to be carried into the distribution system as far as possible, so that difficulties with after-growths, cross connections, etc., may be kept to a minimum.

The appearance of two unexpected hurricanes in the New England area this year has, the author believes, brought more forcibly to our minds the need for adequate standby equipment, ready to go into action at a moment's notice and capable of being operated continuously day after day for prolonged periods. To this end, we are constantly trying to make improvements in the light of past experience, so that a continuous supply of safe water may be delivered to the consumer during periods of emergency as well as during normal periods.

IMPROVEMENTS TO THE NEW BEDFORD WATER SYSTEM

BY HOWARD C. MANDELL*

[*Read December 16, 1954.*]

The first public water supply for the city of New Bedford, the so-called old Acushnet system, was completed in 1869. An artificial reservoir was constructed by damming the Acushnet River at a point about five miles north of the city. From the dam a brick conduit of oval shape, three feet high, carried the water by gravity to a receiving reservoir, located near the center of the city. From this reservoir, the water was pumped by steam power to a distributing reservoir, located about 150 ft above mean high water in New Bedford harbor. This system furnished about 4 mgd to the 27,000 people of New Bedford and continued in use until November, 1899, when the Quittacas system was completed and put into use.

By this time, the population of the city had increased to somewhat more than 60,000, and the use of water for boiler feed by numerous cotton mills with steam-power plants, together with the industrial use of water for other purposes, was an important part of the total consumption. New Bedford differs from most New England cities in that there is no large river passing through it or beside it. The Acushnet river is quite small. Therefore, practically all water used for industrial purposes, except the salt water used for condensing steam, must be supplied by the public water system. The use of water for industrial purposes today constitutes more than 50% of the total pumping.

The Quittacas Pumping Station originally contained two Leavitt walking-beam and fly-wheel, double-expansion steam engines, operating differential pistons in pumps (see Fig. 1), each unit designed to deliver 10 mil gal in 24 hours of continuous operation. Another feature of the Quittacas system was a 48-in. steel force main which was laid a distance of 8 miles to High Hill Reservoir in Dartmouth. The reservoir has a capacity of 65 mil gal.

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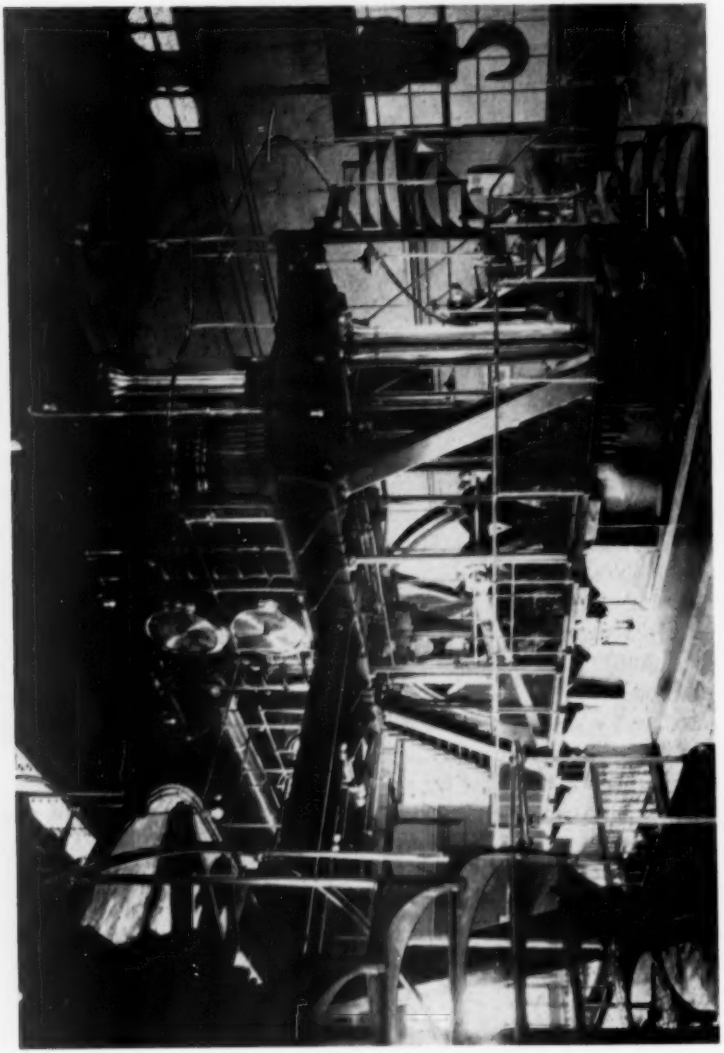

FIG. 1.—TEN-MGD LEAVITT STEAM ENGINE, BUILT IN 1898—ONE OF TWO UNITS WHICH GAVE EXCELLENT SERVICE FOR 50 YEARS.

In 1920 the average daily consumption reached 10 mil gal for the first time, and a centrifugal pump and electric motor, capable of delivering 5 mgd were added to the equipment.

The three aforementioned pumping units, with a total installed capacity of 25 mgd, continued to be adequate to meet the water needs of the city until 1945. In this latter year, the consumption reached 13¼ mgd. At this point, it was realized that the old pumps were inadequate and obsolete. The New Bedford Water Board engaged the firm of Fay, Spofford & Thorndike of Boston to make a study and report with recommendations on the matter of modernizing and increasing the capacity of the pumps for the Quittacas system.

Their report recommended the installation of two 10-mgd centrifugal pumps and one 15-mgd centrifugal pump, all to be driven by synchronous electric motors at 4,160 volts, using power to be purchased from the New Bedford Gas and Edison Light Co. Since there is only one source of electric power and high line to the Quittacas Station, the engineers also recommended the installation of a centrifugal pump with a flexible capacity of 15 to 30 mgd, to be driven by a diesel engine.

The stone building which was built in 1898 to house the original pumping equipment remained in excellent condition, and it was decided to remove the old pumps and install the new equipment in their place. This problem was complicated by the fact that the station had to be operated continuously close to its maximum capacity during the period of dismantling the old pumps and installing the new ones.

The first step was the temporary installation of the new 15-mgd centrifugal pump on a setting outside the building. A temporary suction for the pump was dropped into an intake well and a new temporary delivery line connected it to the force mains, to deliver water to the elevated storage reservoir eight miles from the station.

With this pump in operation, one of the old steam engines was dismantled and the new diesel-driven pump was installed in the space formerly occupied by the old steam pump (see Fig. 2). Then the other old steam pump was removed and the two new 10-mgd pumps were installed in its place.

The last step was to take the new 15-mgd centrifugal from its

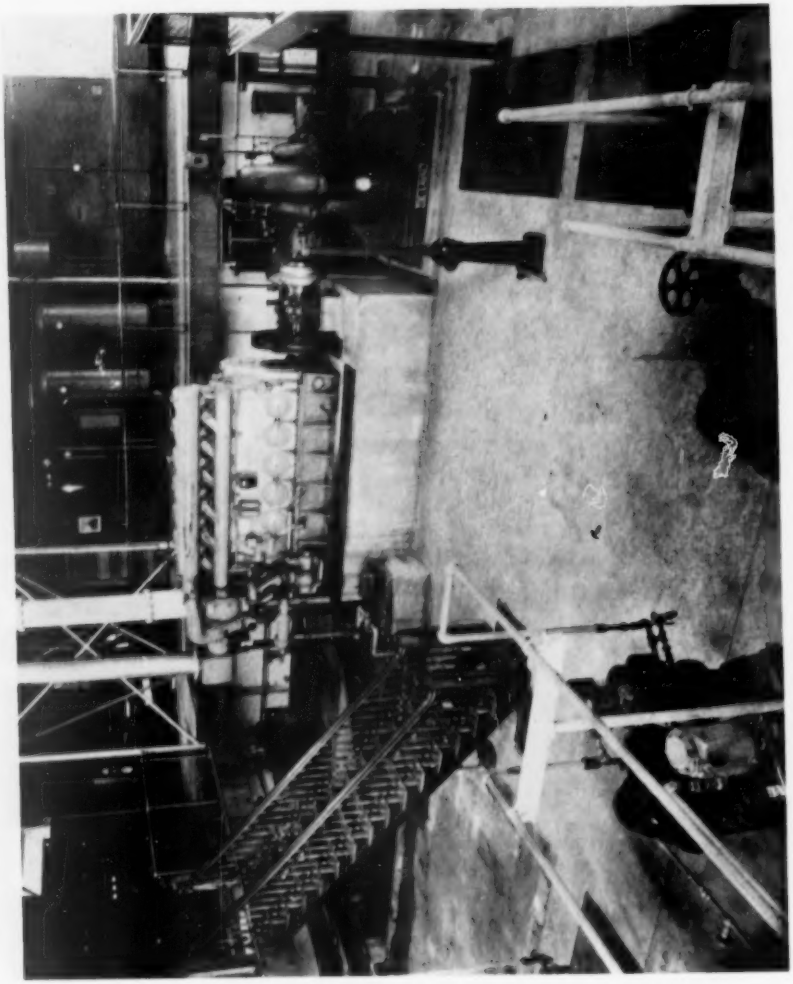

FIG. 2.—BALDWIN 1,000-HP DIESEL AND DIRECT-COUPLED DELAVAL 30-MGD PUMP.

temporary setting outside the building and install it in line with the two 10-mgd units previously installed (see Fig. 3).

The construction proceeded in an orderly way without incident and there was at all times sufficient pumping capacity to meet the needs of the city during the construction period. It is of interest to note that the old equipment which was removed contained enough cast iron, steel, copper, bronze and other materials to make 50 new units of modern design, capable of delivering 10 mgd each.

The selection of the sizes of the units enables us to pump at the rates of 10 mgd, 15, 20 and 25 mgd by electricity, by suitable combinations of units. In case of failure of electric power, there is sufficient storage of diesel fuel oil to permit the continuous operation of the diesel pump at rates varying from 15 to 30 mgd for several months.

The contract with the Turbine Equipment Co. of New England was executed on March 4, 1949, and provided, as subsequently amended, for furnishing and supervising the installation of the following equipment:

Item A.	Two centrifugal pumps,	10-mgd	
	One centrifugal pump,	15-mgd	
	One centrifugal pump,	25-mgd	$26,524.00
Item B.	Two synchronous motors,	400-hp	
	One sychonous motor,	600-hp	17,268.00
Item C.	Electrical switching and control equipment		23,996.00
Item D.	Six-cylinder diesel engine,	1,100-hp	56,100.00
Item E.	Three cone-type check valves		14,692.00
Item G.	Superintending installation of all above equipment, 70 days @ $50.00/day		3,500.00
Item H.	Making field tests of all above equipment, 10 days @ $50.00/day		500.00
Item K.	Performance bond		300.00
		Total	$142,880.00

The contract with T. Loranger & Sons, based upon the only bid received, was executed on August 2, 1949. It provided, among other things, for the removal of existing equipment; installation of all equipment purchased under the contract with Turbine Equipment Co.; construction of a granite screen-house with traveling screen;

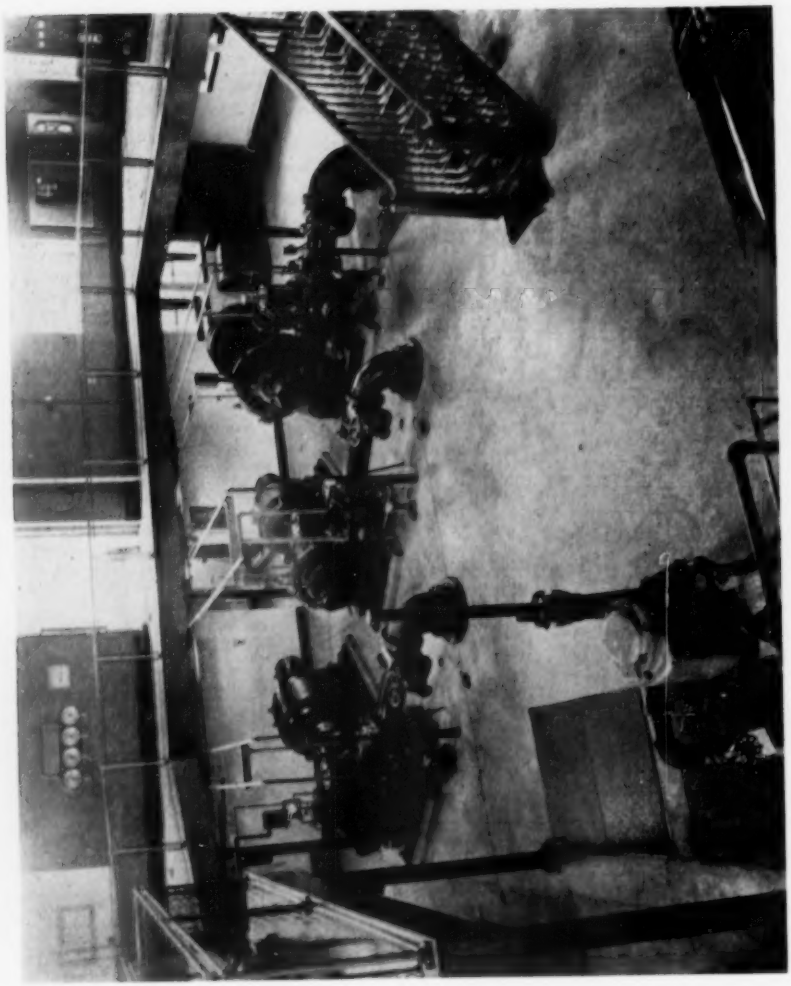

FIG. 3.—TWO 10-MGD DELAVAL PUMPS AND ONE 15-MGD, DRIVEN BY 400-HP AND 600-HP, ELECTRIC MACHINERY SYNCHRONOUS MOTORS.

fuel-oil storage tanks and piping; electrical wiring; furnishing and installing an emergency standby electrical generator, driven by diesel engine; heating and ventilating; alterations to existing structures; excavation, backfill and grading; piping connections from new pumps to existing force mains; and two Venturi meters, to measure the amount of water pumped.

The several items of the contract, as amended by various Change Orders and Extra Work Orders to December 31, 1949, are as follows:

Item 1.	Excavation, backfilling and grading, est. 2,500 cu yd @ $2.00	$5,000.00
Item 2.	Rock excavation, est. 50 cu yd @ $20.00	1,000.00
Item 3.	Earth excavation below grade, est. 25 cu yd @ $4.00	100.00
Item 4.	Selected material, est. 25 cu yd. @ $4.00	100.00
Item 5.	Miscellaneous earth excavation and backfill, est. 25 cu yd @ $6.00	150.00
Item 6.	Lumber and sheeting left in place, est 6 MFBM @ $100.00	600.00
Item 7.	Road paving, est. 300 sq yd @ $4.00	1,200.00
Item 8.	Concrete and reinforced-concrete screen-house (substructure) and pumping station	22,534.00
Item 9.	Miscellaneous Class C concrete, est. 10 cu yds @ $45.00	450.00
Item 10.	Miscellaneous Class E concrete, est. 50 cu yd @ $40.00	2,000.00
Item 11.	Reinforcing steel, est. 500 lb @ $.12	60.00
Item 12.	Screen-house (superstructure), building alterations and fencing	35,578.00
Item 13.	Heating and ventilating	10,625.00
Item 14.	Equipment, piping and appurtenances	132,800.00
Item 15.	Removal of existing equipment	2,400.00
Item 16.	Electrical system	32,000.00
Item 18.	Preparation at site, cleaning up, etc.	10,200.00
Item 19.	Bond	1,215.97
		$258,012.97

In New Bedford, because of the lack of a river containing sufficient water for industrial purposes, the forecasting of future water requirements cannot be based upon anticipated population changes alone. The population of New Bedford today is about the same as it was in 1914. During the middle twenties the population of the

city was 135,000 and the decline since that time is attributed to the decline of the textile industry in New Bedford.

It is significant that the water consumption in 1927 was a little under 9 mgd for a population of about 134,000. In 1953 the water consumption was a little over 19 mgd for a population of about 122,000. The great increase in water consumption, which has occurred during a period when the population has dropped about 10%, is explained by the establishment in New Bedford of several industries requiring large amounts of water, on the order of 1 mgd each. Last year 22 accounts used more than 94,000 gal per day each, and 14 of these averaged more than 682,000 gal per day per account. These 22 industries used approximately 57% of all water metered during the year.

The city of New Bedford is actively engaged in an attempt to attract new industries and the future use of water would seem to depend more upon the success of these activities than upon a growth in population.

For the year 1953, the three electric pumps had a wire-to-water average efficiency of 80%. With an average cost of 11.3 mills per kilowatt-hour, the cost of electric power to raise one million gallons one foot was a little less than $.045.

The diesel-driven pump was operated during one eight-hour shift each week last year. It required 0.27 gal of No. 2 diesel fuel oil to raise one million gallons one foot. With an average delivered cost of $.11 per gallon of fuel oil, the cost of *fuel only* to raise one million gallons one foot was about $.03.

It is believed that these costs and efficiencies compare favorably with the best modern practice.

The average cost of raising one million gallons one foot, based upon all pumping-station expenses, was $.10. This figure happens to be the same as the average cost reported by some eight municipal water works in 1877, when the costs of fuel and labor were about one-quarter of today's costs.

The pumps were made by the DeLaval Steam Turbine Co.; motors and controls by Electric Machinery Co.; diesel engine by Baldwin-Lima Locomotive Co.; and automatic cone-valves by S. Morgan Smith.

The total cost of the modernization of the pumping equipment was about $500,000. It was paid for by the sale of serial bonds under provisions of the General Laws of Massachusetts, with interest at 1½%.

Another improvement has been the erection of an elevated storage tank, to improve pressure for domestic use of water and for fire protection in an area of high ground in the northwesterly part of the city. The tank is of the hemi-ellipsoidal type, with a capacity of 350,000 gal, on a hexagonal tower of H columns. The tank was manufactured and erected by the Pittsburgh-Des Moines Steel Co. This undertaking, which cost about $45,000, has remedied the poor-pressure conditions on the high ground.

The firm of Fay, Spofford & Thorndike is currently making a study to find the best remedy for low-pressure conditions throughout the city of New Bedford on days of peak consumption during the summer, when the use of water for sprinkling, air conditioning, and industrial cooling purposes combines to create a daily demand which is about 140% of the average daily demand, and an hourly peak which is about 200% of the average daily demand. It is hoped that their report will be rendered soon and that work may be undertaken next year to supply adequate pressure throughout the city at all times.

MECHANICAL-JOINT CAST-IRON PIPE

BY THOMAS F. WOLFE*

[*Presented at Superintendents' Round Table, Jan. 20, 1955.*]

Cast-iron pipe has been used for water supply and distribution lines for almost 300 years. Joints used in the earlier installations were flanged and since machining operations were still unknown, the joints relied for tightness on a thick lead gasket. As time went on, a crude bell-and-spigot joint was developed and various types of jointing materials were used. Mixtures of tar and sawdust were tried—wooden wedges were used, and it is also recorded that at one time a mixture of cream cheese and lime was used. All of these early bell-and-spigot joints gave trouble when subjected to pressure and in about 1785, Thomas Simpson, Engineer of the Chelsea Water Company in London, devised our present-day bell-and-spigot joint, using calked lead as a jointing material. This type of joint, with certain refinements, was used almost exclusively for underground installations until toward the end of the 19th century, when sulfur-compound jointing materials were first developed and used to a limited extent in place of lead. Sulfur compounds, while having the advantage of low cost, never replaced lead. About 50 years ago, Portland cement joints came into use in certain parts of the country, but in general, lead joints were most generally used for both water and gas distribution.

The lead joint had many advantages, but it was inclined to leak when movement of the pipe occurred. The amount of leakage was usually small, but in the case of gas distribution systems, even a small leak is objectionable. The small gas leaks that were found when manufactured gas was distributed became larger leaks when natural gas replaced manufactured gas. This was due to the fact that natural gas, being drier than manufactured gas, absorbed the moisture

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Editor's Note: This paper was previously presented at a section meeting of the American Water Works Association.

from the jute in the joints. The fact that calked lead joints did not give perfect satisfaction for this service suggested that a new type of joint be developed. This resulted in the designing of the present mechanical joint.

The mechanical joint, as we now have it, combines the tightness of a flanged joint with flexibility greater than that of a bell-and-spigot joint. In the course of its development, it was first used on small-diameter pipe that was used principally for industrial purposes, for mine drainage, and for other installations where it was desirable that the pipe be readily disassembled for use in different locations. The use of this type of joint in sizes ordinarily used in water distribution dates back to about 1925. For the first few years after its introduction, it was used mainly for gas-distribution work. As a result of its success in this field, over 90% of all cast-iron gas pipe that is sold today is equipped with mechanical joints. Recognizing its success in the gas industry, water-works men soon began to purchase it for water-works use, until now a large percentage of all water pipe 12 in. and smaller in diameter is equipped with mechanical joints, and a growing percentage of larger-diameter pipe.

At one time, each producer of cast-iron pipe had his own particular design for this joint, but as time went on it became evident that standardization of the joint was desirable from the standpoint of the pipe user. Prior to standardization, there were dimensional differences in the parts in the joint, that made it impossible to use a part manufactured by one company with the pipe manufactured by another. Since 1942, all mechanical joints made by members of the Cast Iron Pipe Research Association are made to exactly the same dimensions. Gaskets furnished by one company may be used with follower rings furnished by a second company and, in turn, both may be used on pipe furnished by a third company.

At the request of the gas industry, the American Standards Association was asked to develop a standard specification for this joint. This specification, which covers both gas and water uses, was adopted as an American Standard on January 13, 1953. The dimensions of the joint are shown in Table 11.1 of A. S. A. Specification 21.11. It is to be noted that close tolerances are specified. It is also to be noted that the gasket in this joint is closely confined, and that the

joint is designed so that very little of the gasket comes in contact with either the water or the soil. Most mechanical-joint pipe is furnished with plain rubber or synthetic rubber gaskets. For water-works use, in those places where electrical thawing of pipes or services might become necessary, the use of a lead-tipped or armored gasket is advisable, since a perfectly made-up joint, using a plain rubber gasket, could be a perfect insulator and prevent flow of current through the pipe to be thawed. Lead-tipped gaskets are also used where wet manufactured gases are transported.

The bolts used in the joint for ordinary installations are made of high-strength cast iron and, consequently, have the same corrosion-resistance characteristics as the pipe itself. The number and size of bolts are shown in Table 11.1.

The principal advantages of the mechanical joint are:

1. Tightness
2. Economy
3. Flexibility
4. Absence of hemp or jute, which could support bacterial life
5. Simplicity of installation

The joint, when properly made up, is bottle tight. This is evidenced by the fact that in many gas installations, particularly those of large diameters and those that carry high pressures, specifications frequently require that each joint be tested with air pressure while the joint is submerged. If any evidence of leakage occurs, the joint is gone over until perfectly tight. In ordinary practice, so few leaks have been found that some companies now require no more testing with this type of joint than they did with lead joints.

With regard to economy, it is a fact that, even though the pipe as sold costs more per foot than bell-and-spigot pipe, the price paid includes all jointing material. This fact, coupled with the fact that the joints are easily made up and can be made under conditions where lead joints would be difficult to make, keeps the cost down. In many places where alternate bids have been taken on lead joints and mechanical joints, contractors have bid a lower price for the complete installation with mechanical joints than they did with lead joints.

Where mechanical joints are used, no lead kettle is necessary, no pneumatic hammers or compressors are required, and there is no need for the miscellaneous supplies that enter into the making of lead joints.

The joint is more flexible than any other type of joint, due to two things. First, the shape of the bottom of the socket is such that the spigot end of the pipe may move an appreciable amount before there is an iron-to-iron contact, and secondly, when the pipe deflects, the gasket itself forms the fulcrum. Not only is this flexibility desirable from the standpoint of any settlement that may occur, but it also permits laying pipe around curves without in any way affecting the tightness of the joint. It further permits the assembly of the pipe above ground, when such assembly is desirable, and the lowering of the pipe into the ditch as the work progresses. This method of installation may become necessary in wet soils or for submarine work and is frequently used on ordinary work in order to reduce costs.

From the standpoint of contamination of the water, the absence of hemp or jute is highly desirable. While hemp and jute, or any other vegetable gasket, can act as a host for bacteria, rubber does not furnish a feeding ground; from its nature is easily cleaned before installation, and can be placed in the joint in a clean and sanitary condition.

The simplicity of the joint makes for ease of installation, the joint having only three parts: gasket, follower ring and bolts. Since its makeup requires only the use of a ratchet wrench to tighten bolts, little skill is required and what little is required is soon learned.

The process of making up the joint is as follows:

The spigot and bell of the pipe are cleaned with water and a rag, sponge or waste (Fig. 1). The purpose of this operation is to make sure that no sand or grit remains on the surface of the pipe to interfere with proper seating of the gasket. The cast-iron gland is then placed over the spigot, approximately 10 in. back from the end. A rubber gasket that has been cleaned in a pail of water is then placed over the spigot, with the tapered side facing the bell. The spigot is then again cleaned and inserted in the bell (Fig. 2). The gasket is then forced home with the fingers until it is flush with the face of the bell (Fig. 3), the gland is moved up, bolt-holes are lined up, and

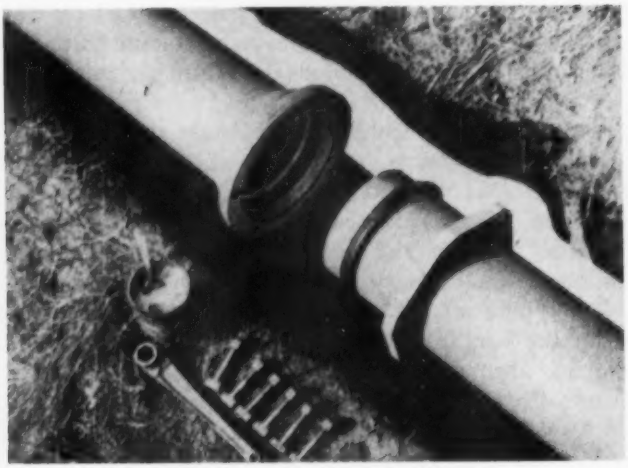

FIG. 1.—WASH SOCKET AND PLAIN END WITH SOAPY WATER, THEN SLIP GLAND AND GASKET OVER PLAIN END. SMALL SIDE OF GASKET AND LIP SIDE OF GLAND FACE BELL.

FIG. 2.—PAINT GASKET WITH SOAPY WATER.

cast-iron bolts are inserted. All nuts are then made hand tight (Fig. 4) and then tightened with a ratchet wrench, beginning at the top and tightening bolts on opposite sides (Fig. 5). This results in all bolts being drawn up evenly and keeps the face of the gland parallel to the face of the bell. The bolts are properly tightened when a 10-inch wrench is used by the ordinary workman. The completed joint is shown in Fig. 6.

When first using this type of pipe, it may be desirable to use a torque wrench, set for the values shown on page 5 of the A. S. A. Specifications. In a short time the men become accustomed to the amount of effort necessary and the torque wrench need then be used only to make an occasional check. Using a longer wrench or placing a piece of pipe over the end of the wrench, in order to get a greater purchase, is undesirable, adds nothing to the tightness of the joint, and may cause bolt failure.

Tests on gas lines, constructed with mechanical joints, have shown them to be bottle tight and in at least one case, where a water line was to be installed and the specifications required zero leakage, seven contractors bid on the work, indicating confidence in their ability to make the joints perfectly tight.

Those who have not used this type of joint normally raise certain questions regarding it. First of all, many are concerned about the life of the gaskets. It is a fact that rubber gaskets have been used in underground pipe construction work for over 80 years. The writer has seen a gasket used in a rather crude underground joint where, after 60 years of service, the rubber still could be stretched and had all the appearances of new rubber. The mechanical joint is so designed that the rubber gasket is, to all practical intents and purposes, completely confined. Since rubber deteriorates only when subjected to air, light or heat, this design practically insures an unlimited life for the gasket.

The second question that comes up is whether or not synthetic rubbers are as satisfactory as natural rubber. The physical tests on synthetic rubbers show that they have all the characteristics of natural rubber, insofar as tensile strength, elasticity, and cold flow are concerned, and those who have used both types of rubber are satisfied that synthetic rubber will give the same service as natural rubber.

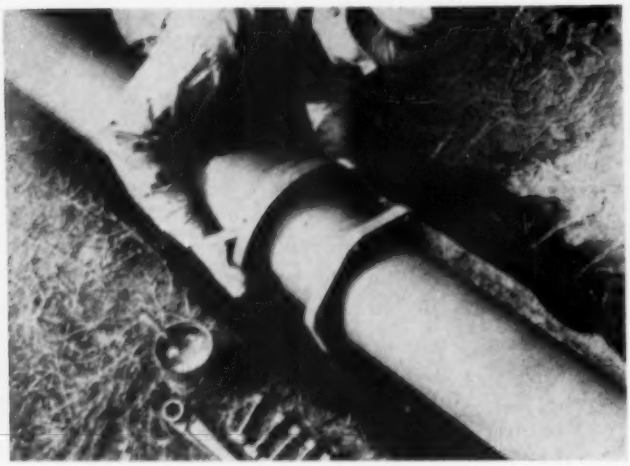

FIG. 3.—PUSH GASKET INTO POSITION, MAKING SURE IT IS EVENLY SEATED IN SOCKET.

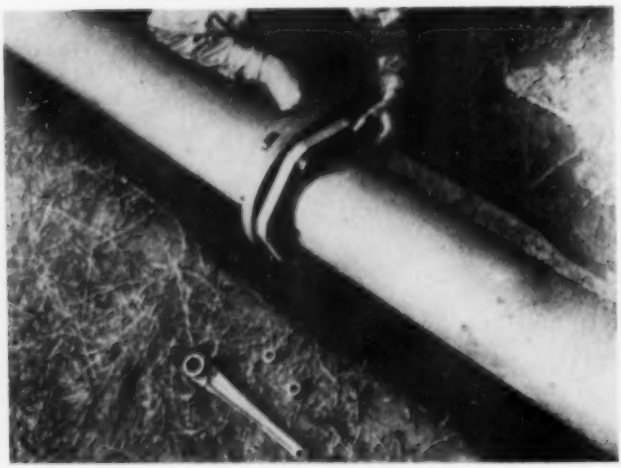

FIG. 4.—SLIDE GLAND INTO POSITION, INSERT BOLTS AND RUN NUTS UP FINGER-TIGHT.

Fig. 5.—Tighten Bolts to Uniform Tightness with Ratchet Wrench. Bolts 180° Apart Should Be Tightened Alternately in Order to Bring Up Gland Evenly All Around, i.e., First Bolt to Be Tightened Should Be at Bottom of Joint, Second Should Be at Top of Joint, etc.

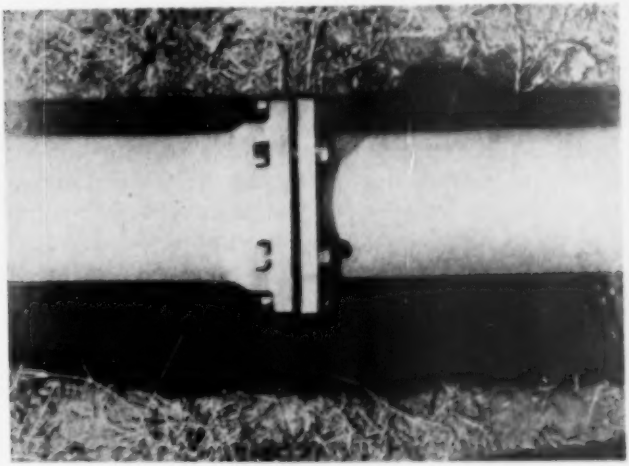

Fig. 6.—The Completed Joint.

The next question that comes up has to do with life of bolts. In the past, some trouble due to bolt failures has been experienced with bolted-joint pipe having a metal-to-metal contact. These bolts were steel bolts and usually smaller in diameter than the bolts furnished with mechanical-joint pipe. The bolts in mechanical-joint cast-iron pipe are made of cast iron.

Another question commonly asked is whether or not water mains, installed with mechanical joints, can be thawed electrically. As stated before, the use of lead-tipped or armored gaskets permits current to travel through the joint and, consequently, permits of electrical thawing.

Another question that has been raised has to do with whether or not the motion of the pipe inside the gasket might not cause abrasion of the gasket with a resulting leak. As a matter of fact, the slight motion that does take place with temperature changes takes place within the rubber, the gasket remaining fixed with regard to the spigot and to the inside of the bell, and consequently no abrasion can occur.

The value of any material is determined by its record of performance under actual field conditions. After 25 years' use in underground construction of water and gas mains, mechanical-joint pipe has proved to all intents and purposes to be the perfect pipe for underground construction.

DIATOMACEOUS EARTH FILTRATION

BY HENRY N. ARMBRUST*

[*Read at Chemists' Round Table, Jan. 20, 1955.*]

In view of present developments and future expectations, use of the term "diatomaceous earth filtration" is somewhat restrictive. It is more realistic to speak of "filter-aid filtration" and "filter-aid filters". Although diatomaceous earth is by far the most common filter-aid material in use today, there are several other materials used in this type of filtration. These include: Wollastonite, expanded perlite, granular cellulose materials, asbestos fibre, activated carbon and other finely divided substances.

Essentially, a filter-aid filter consists of a layer of finely divided particles deposited upon a porous supporting membrane, which serves as an underdrain. The size of the particle is such that the pores, or openings between them, are ultra-microscopic. When water is passed through the layer, suspended matter is caught on the surface and thus removed from the water or other liquid.

Filter-aid filtration developed from the use of unglazed porcelain and other similar materials as filtering media for a very high degree of turbidity removal. The unglazed porcelain filter is very efficient in the removal of microscopic particles, including bacteria, but filter runs are short, rates are extremely low and cleaning the filter is difficult. The use of an easily removable mat of finely divided particles as a filter medium was an advance in the art which took this type of filter out of the laboratory and put it into common use.

History

Filter-aid filters were used for many years prior to 1940 for the filtration of beer, wines, oils and chemicals. It was not until World War II, however, that the filter-aid filter for the continuous purification of drinking water became a practical reality. The next step was the application of these filters to domestic use.

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At the beginning of the war, American troops and the land forces of the Navy were supplied with small, portable, sand-filter plants, which provided flocculation, coagulation and sterilization. Under field conditions, this type of purification plant was not efficient in removing amoebic dysentery cysts and blood flukes. Meanwhile, the British were using a diatomaceous earth filter in their portable water-purification plants and this type of filter was found to be capable of turning out acceptable water.

At the suggestion of the National Research Council, the U. S. Army undertook the development of a portable, diatomaceous earth, water-purification unit at Fort Belvoir, Va. Subsequently, the U. S. Navy contracted with Proportioneers, Inc. for the development of a portable, diatomaceous earth, filter plant for use by the Navy Civil Engineers Corps. These developments proceeded independently of each other. At the end of the War the U. S. Navy had some 1,500 units, many of them in use at advanced bases in Okinawa and other locations, and the U. S. Army also had a number of units.

Design Features

Both of these military units used cylindrical, or tubular, filter elements; both used a precoat or initial filter mat, plus a continuous feed of diatomaceous earth, termed "body feed", into the incoming water. (Body feed is used to prolong filter runs by maintaining an open porous cake.) Here the similarity ceased.

The Army unit was operated at a constant input pressure. Thus, with a clean, new precoat the filtering rate might run up to 10 gal per minute, but as the pressure loss increased, the rate fell off until it reached a point below that required. The filter-aid was fed by a constant dilution device. Army Engineers believed that the decrease in filtering rate caused by the clogging of the filter cake (and consequent increase in pressure loss) followed the dilution curve; thus it was believed that the rate of body feed would be in proportion to the rate of flow of water through the filter.

Backwashing was accomplished by setting a four-way valve so that the inlet to the filter (connected with the pressure side of the supply pump during the filtration part of the cycle) was connected to the suction side of the pump and the filter was backwashed by

suction. The Army filter elements were patterned after the British Stellar element, consisting of Monel metal or stainless steel, round wire, wound on a perforated plastic core.

The Navy unit consisted of a machinery section which was a frame, holding: (1) water pump; (2) duplex-positive-displacement-pump-type feeder for hypochlorite and filter-aid slurry; (3) pump engine with belt drive to pump; (4) hypochlorite reservoir, and (5) baffled tank with an agitator, driven through a flexible cable from a shaft of the feeder. The filter, separate from the machinery section, contained porous aluminum-oxide tubes as septa and was equipped with a rate-of-flow indicator, graduated in gallons per minute.

This purification unit was operated at a constant rate and diatomaceous earth body feed was fed in a predetermined direct proportion to the rate of flow. Pressure backwashing was accomplished by a separate pump, using filtered water taken from a storage tank. The use of this purification unit enabled the Navy Civil Engineer Corps to take water from such polluted sources as rice paddies and to deliver a safe, potable product to their personnel.

Subsequent to the presentation of papers on these units at the Engineers' Society of Western Pennsylvania in the mid-40's, several manufacturers became interested in diatomaceous earth filters. The result was that several types of equipment were offered as "cure-alls" for many water-filtration problems. Lacking proper background and experience in the field, the efforts of some of these manufacturers resulted in failure of equipment to perform properly. Some of these firms have since discontinued manufacturing these units, but the damage caused by lack of experience and misapplication of the equipment delayed the proper development and use of filter-aid filters.

Principles of Operation

Now let us consider how the filter-aid filter resembles a sand filter. The sand filter, either the rapid sand or the slow sand type, consists of an underdrain system of collecting pipes with superimposed layers of coarse stone, coarse gravel, fine gravel, coarse sand and, finally, fine sand at the top. In the rapid sand filter, these layers exist in either an open tank (gravity filter) or a closed tank (pressure

filter). Slow sand filters are of the open or gravity type. Direction of flow in both types is downward through the filtering medium. A sand filter is not a completely effective filtering unit until a gelatinous filtering mat has been deposited on and in the top layer of sand. In the rapid sand filter the mat is chemically precipitated floc. The filtering mat in the slow sand filter is a "schmutzdecke" of gelatinous material, which is removed from the water as the filter is operated to waste.

In the filter-aid filter, the cylindrical shell is divided into two compartments by a separate plate, or tube sheet, containing a number of holes. The elements or septa are porous cylindrical tubes, closed at one end, open at the other. The open end of these tubes is inserted into the holes in the separator plate. Clamps, tie rods and bottom caps hold the cylindrical tubes tightly against the holes in the separator plate. Flow direction is opposite to that of a sand filter. Water enters the bottom or raw-water compartment, passes through the filtering tubes, and up into the filtered-water compartment. On these tubes is deposited a filtering mat or "precoat" layer of diatomaceous earth, approximately one-tenth of an inch thick. This precoat of filter-aid is held on the surface of the tubes by the flow of water and slight pressure differential between the two compartments.

The section of the filtering mat is similar to the schmutzdecke of slow sand filters. Inasmuch as the particles of filter-aid are microscopic, the openings through the mat are devious and are ultramicroscopic; therefore, foreign matter is effectively entrapped on the surface of the filtering mat. As flow continues, more and more suspended and colloidal matter is caught on the filtering mat (see Fig. 1). If flow were allowed to continue under these conditions, the mat would become clogged, the rate of flow would decrease to a low value and the pressure loss would increase, thus making operation uneconomical.

To avoid this clogging action, a constant addition of filter-aid is made in the proper proportion to the rate of flow. This is known as "body-feed". Body feed extends the length of filter runs up to 1,000% or more, by continually building up the cake, separating the particles of foreign matter and preventing the total clogging of the openings. The dosage of body feed is critical up to an optimum pro-

portion, in that a slight reduction of the dosage will result in a marked decrease in length of filter run. Above the optimum body-feed rate, however, a relatively large increase in dosage will produce only a slight reduction in length of filter run.

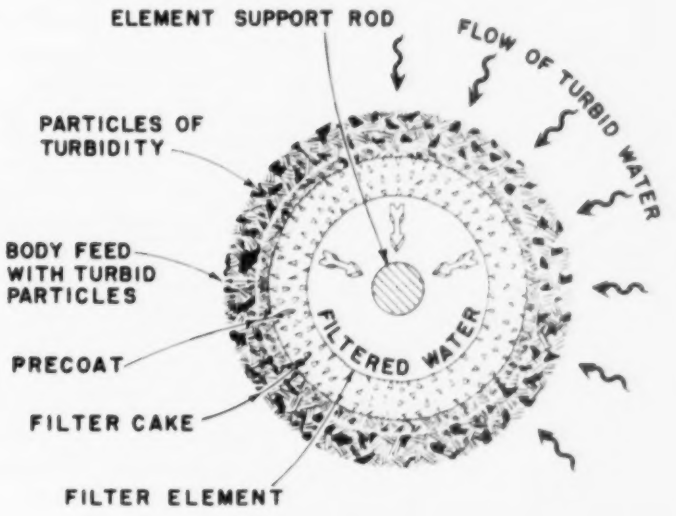
ELEMENT SUPPORT ROD
FLOW OF TURBID WATER
PARTICLES OF TURBIDITY
BODY FEED WITH TURBID PARTICLES
FILTERED WATER
PRECOAT
FILTER CAKE
FILTER ELEMENT
FILTER AREA IS INCREASED AS FILTER CAKE GROWS PERMITTING MUCH LONGER RUNS AT HIGHER RATES

FIG. 1.—DIAGRAM OF FILTER CAKE AND PRECOAT ON ELEMENT.

Backwashing

In the case of the rapid sand filter, backwashing is accomplished by reversing the flow through the filter, at a rate approximately three to five times the normal filtration rate. In this manner, the sand bed is expanded, the grains are separated by the velocity of the water and agitated until they have scrubbed themselves free of the filtering mat material, which is carried out to waste. Backwashing normally requires about an hour's production of water by the filter. Slow sand filters are usually drained and the top inch or so of sand

and accumulated schmutzdecke is removed with rakes and shovels. In each case, before resuming filtration, a new mat is built up as the filter is operated to waste.

Most filter-aid filters have an air chamber in the filtered water section, where air is entrapped. At the end of a filter run, which is determined by a decreased rate of flow or an arbitrary limit of pressure loss, the effluent line is closed. Closing this line causes the pressure in the filtered-water section to build up to the cut-off head of the pump (if one is used), thus compressing the air. If the flow is by gravity the pressure is built up to the maximum static influent pressure. Next, the influent valve is closed and a quick-opening backwash drain valve is opened. The pressure in the raw-water section immediately decreases toward zero and causes an explosive expansion of the air trapped in the top of the filter. This sudden expansion of air drives the water in the upper section back through the filter elements. This reverse flow, momentarily at rates of several hundred gallons per minute per square foot, literally blasts the accumulated filter cake loose.

An air vent is then opened and the filter is drained and rinsed. A new precoat is applied and the filter returned to service. Backwashing in this manner requires approximately two to three times the volume of water contained in the filter shell, a volume equivalent to only a few minutes' filtered-water production.

Types of Filters

There are several types of filter-aid filters, practically all of which have rigid septa, on which an initial filtering mat or precoat is formed. Perhaps the oldest and most widely used in industry are the plate-and-frame filter and the leaf filter, which must be dismantled and cleaned manually after every filter run. The majority of filters used in municipal water works and swimming pools are pressure filters of the tubular-element type. In the filter-aid filter, a 30-inch-diameter shell can contain as many as fifty-five 2½-inch-diameter elements more than 4 feet long, making a total area of approximately 156 sq ft of filter surface. Contrast this with approximately 5 sq ft of area of a sand bed in a 30-inch shell.

Besides the pressure filter with tubular elements, the plate-and-

frame filter, and the pressure leaf filter, there is a vacuum filter with tubular elements, as well as a vacuum-drum filter. The former consists of an open tank, containing an underdrain system and a multiplicity of tubular elements, extending upward. This filter is the nearest approach to a conventional rapid sand filter. A pump takes suction from the underdrain manifold and consequently the maximum differential head across the elements is approximately 25 ft of water. The drum-type filter is essentially the same as the vacuum sewage filter, except that the drum is precoated with approximately two inches of filter-aid. As it revolves, a knife removes the filter cake and one or two thousandths of an inch of the initial precoat, thus continuously exposing a new surface to the liquid being filtered.

Filter Elements

Several different types of filter elements are available. These include wire or plastic cloth; round wire, wound in grooves on a central perforated core; trapezoidal, self-spacing, stainless steel ribbon, wound on edge on a perforated metal core; porous, sintered aluminum oxide (Fig. 2); heavy trapezoidal wire, wound and spot-welded to a perforated metal core (Fig. 3); and porous, elastic plastic or rubber on a heavy wire-mesh core. Each of these elements has its advantages and disadvantages.

The ideal element is one which is chemically inert and, therefore, resistant to corrosion. It must be rigid, to prevent cracking of the filter cake through movement of the supporting septum, as the pressure differential varies across the element. It should backwash easily and cleanly, with even distribution of the backwash flow, and it should be capable of being chemically cleaned without removal from the shell. Above all, it must take an even precoat, which means that it must be homogeneous as to permeability, and it must be relatively inexpensive.

The wire and the porous stone elements are the most widely used in present-day filter-aid filters. While the wire-wound element is easier to clean mechanically, it is expensive and chemical cleaning can cause disintegration. The porous stone element is harder to clean mechanically, but is readily cleaned chemically. It is, however, more fragile. In recent years, aluminum oxide is the only material which

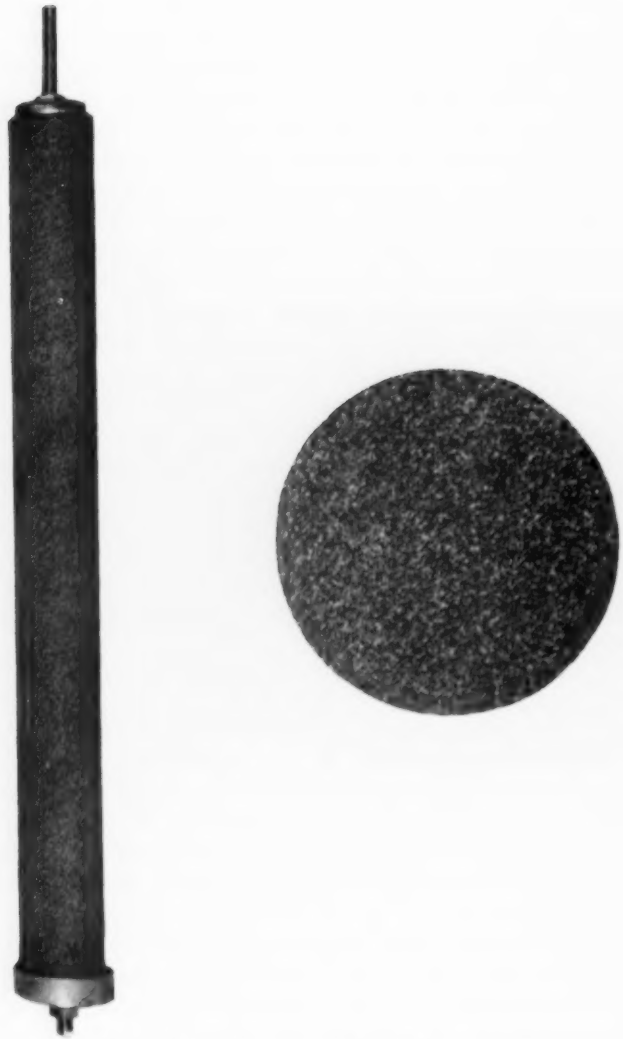

FIG. 2.—POROUS ALUMINUM-OXIDE-TYPE ELEMENT.

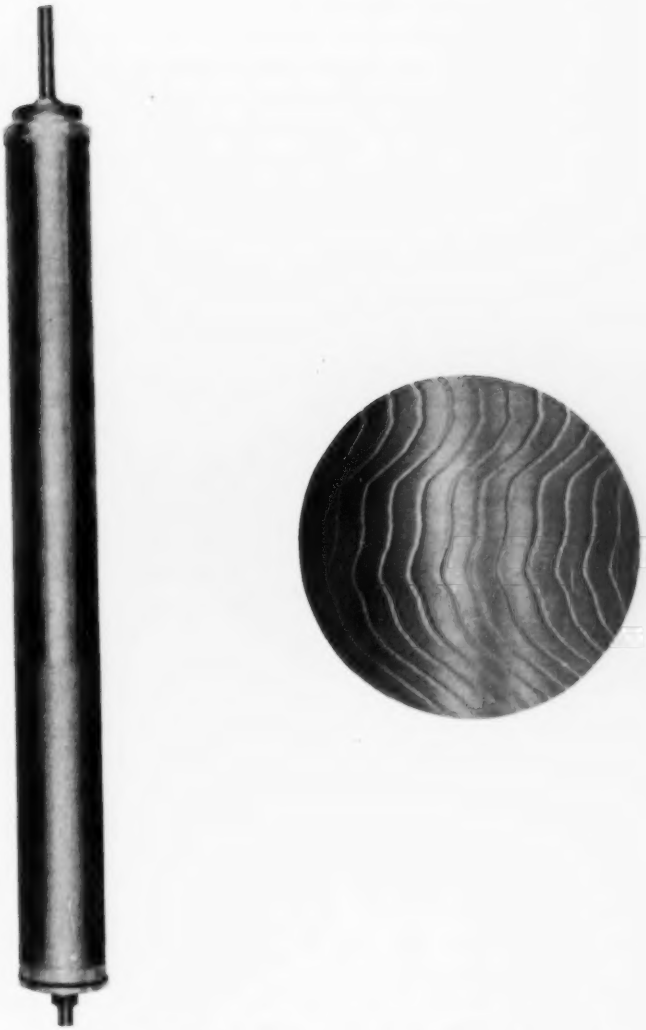

FIG. 3.—TRAPEZOIDAL STAINLESS-STEEL RIBBON-TYPE ELEMENT.

has been used for porous stone elements. Some published articles, in the past, have referred to "carborundum elements", but this is a misnomer through association with the name of one of the manufacturers of aluminum-oxide tubes. Carborundum is actually silicon carbide, which has not been employed as a standard-production filter-element material.

Filtering Rates

Filtration rates with filter-aid filters are gradually being standardized at not more than one gpm per sq ft for industrial or municipal applications, and not more than 3 gpm per sq ft for swimming-pool applications. There is a growing tendency to limit permissible swimming-pool filtration rates to an even lower figure. Generally speaking, filtration at rates up to 10 gpm per sq ft will produce water of satisfactory quality and there are some manufacturers who recommend their filters for operation at rates well above those mentioned. The lower rates assure much longer runs and a greater degree of freedom from trouble.

Operation

The filter-aid filter is unsurpassed for the removal of turbidity, producing a water with only 0.1 to 0.2 ppm of turbidity, or less, even when filtering turbidities as high as 100 ppm. It is efficient in the removal of algae. It is not recommended for a high degree of color removal, where the color is true color due to tannic and humic acids. With the proper filter aid, effective removal of bacteria by a filter-aid filter is similar to the removal of bacteria with slow sand filter.

Although the filter-aid filter is not recommended for true color removal in water supplies, when used in swimming pools where the water is recirculated, color removal is normally satisfactory.

In swimming-pool filtration, it is recommended that chlorine be applied after the water has passed through the filter, particularly in cases where the make-up water contains iron or manganese. In these cases, it is desirable to add make-up water over the edge of the pool, or through a make-up tank leading directly into the pool, rather than into the suction of the pump. It is desirable, also, to maintain the hardness of the water and the pH at a level which will prevent

corrosion of piping and consequent dissolving of iron, which will later precipitate in the filter elements. Where iron-bearing waters are brought directly into a pool and proper conditions are maintained, the iron will precipitate and agglomerate in the pool, thus forming particles large enough to be caught on the filter cake, rather than penetrating it and plating out on the elements. Filter shells and steel parts should be adequately coated to prevent corrosion.

Problems

Troubles in the field have been mainly of two types: misapplication and difficulties of a chemical nature. Misapplication has resulted from improper engineering, caused by lack of understanding of the capabilities of filter-aid filters, or by the desire of a manufacurer to employ excessive filtering rates by reducing filter area to lower sales prices.

Troubles of a chemical nature include floc carry-over, iron and manganese, and electrolytic corrosion. If coagulant floc is carried over to the filter, the filter cake can be blocked very quickly.

Iron and manganese in solution will tend to plate out on the element, blocking it and requiring chemical cleaning. Where iron and manganese are present, preventive maintenance programs have been instituted, in which the filters are periodically chemically cleaned by means of muriatic or oxalic acid for iron removal, and acid and sodium acid sulfite for manganese.

Metal filter elements and other parts are corroded by electrolysis, due to the use of dissimilar metals. In some cases, slimy impurities present in excessive amounts can cause rapid blocking and consequent short runs. Sometimes, short runs of only a few hours are encountered with very low turbidities, where the turbidity is of a slimy or flocculant nature, whereas there have been cases of runs of 18 hours' duration while filtering water with turbidities of about 100 ppm, much of which was algae. Thus the turbidity value is not an indication of the length of run which might be expected, as the reading does not take into consideration particle size, color, shape or character.

What of the Future?

Filter-aid filters are at present used in many industrial water-supply installations and also in an increasing number of municipal

FIG. 4.—INSTALLATION OF PURECEL FILTERS AT TUPPER LAKE, N. Y.

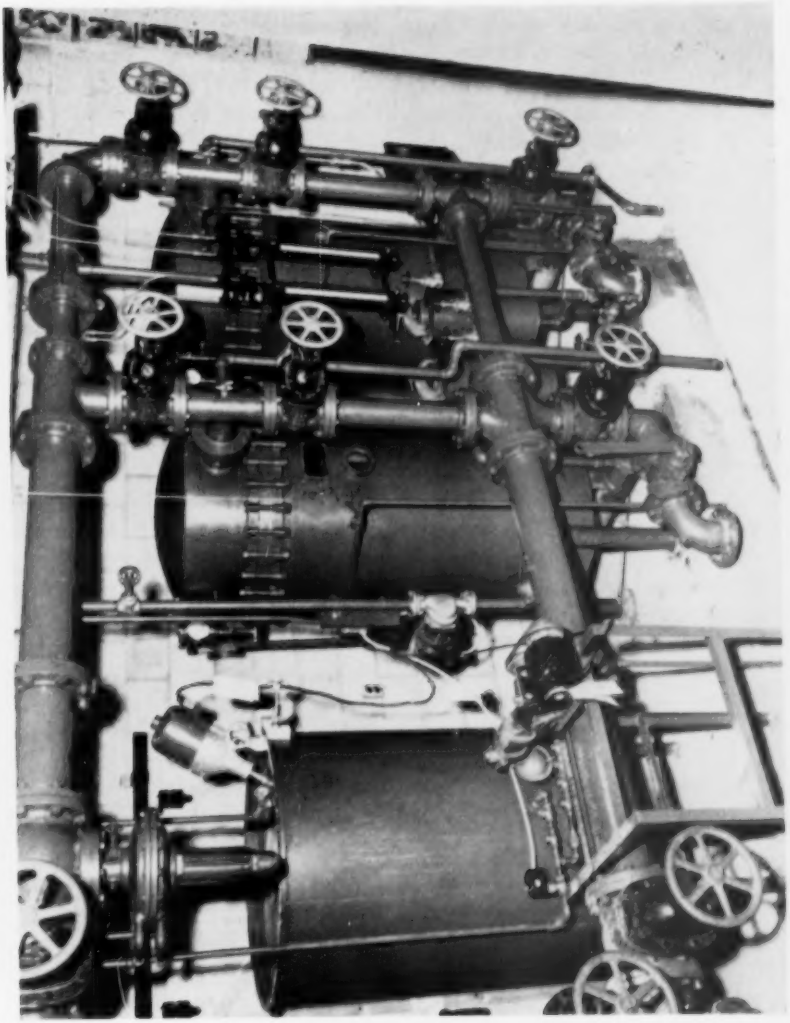

FIG. 5.—INSTALLATION OF PURICEL FILTERS AT BANGOR-MONITOR TOWNSHIP, MICH.

installations, ranging from water plants with a capacity of a few thousand gallons per day up to 2 mgd. Representative municipal installations include Cherry Valley, N. Y., Willsboro, N. Y., Sherburne, N. Y,. Gasport, N. Y., Tupper Lake, N. Y. (Fig. 4), Bangor-Monitor Township, Mich. (Fig. 5), Mounds, Ill., and others.

To those who contemplate the possibility of using filter-aid filters in municipalities, it is recommended that thorough studies of the water be made by a competent engineer and that a pilot plant be operated during those periods of the year when the turbidity of the water is highest, as well as in the algae season. The water should be chemically conditioned to reduce the possibility of corrosion or precipitation of scale.

The development and employment of the filter-aid filter for municipal water-supply filtration is the first major step forward in the filtration picture in many years. Research is being carried on with various types of filter construction and with various types of septa. Work is also being done on the problem of establishing a measure of filterability. Filter-aid manufacturers are busily engaged in the testing of new materials. The next ten years will bring the development of new filter aids and techniques, which will enable the filter-aid filter to be used in even the largest water plants with a very great saving in construction and operation costs.

NEW AND INTERESTING FEATURES IN RELATION TO GRAVEL-PACKED WELLS AND PUMPING PLANTS AT PROVINCETOWN AND CENTERVILLE-OSTERVILLE, MASS.

BY PAUL F. HOWARD*

[*Read January 20, 1955.*]

The town of Provincetown first constructed a municipal water system in 1893 and secured its water supply by means of pipe wells, located north of the village in the sand dune area which was covered with vegetation (see Plate 1). Within two years there were many complaints about the high iron content of the water. After many unsuccessful attempts to correct the conditions this water supply was abandoned and a new water supply was established in North Truro. It was found that although sufficient water could be obtained from wells located in the sand dune area, the water always contained an objectionable amount of iron, due to the organic matter that had been buried in the sand during the formation of the dunes.

Therefore, it was decided to locate a new supply at the nearest satisfactory location, which was in North Truro about five miles from the business center of Provincetown. It was found that this area was free of buried organic matter and the ground water was low in iron content. Plate 2 shows how this area was formed.

Provincetown's North Truro Pumping Station

In 1949 it was decided to replace one of the two original steam-engine-driven pumps with a diesel-engine-driven pumping unit. This presented two major problems: one, the excessive suction lift and the other, automatic control of the rate of pumping, in order to prevent damage to the wells and also the entrance of salt water into the wells, due to overdraft.

The steam-engine-driven pumps, which were to be replaced operated with about 27 ft of suction lift during periods of low ground-

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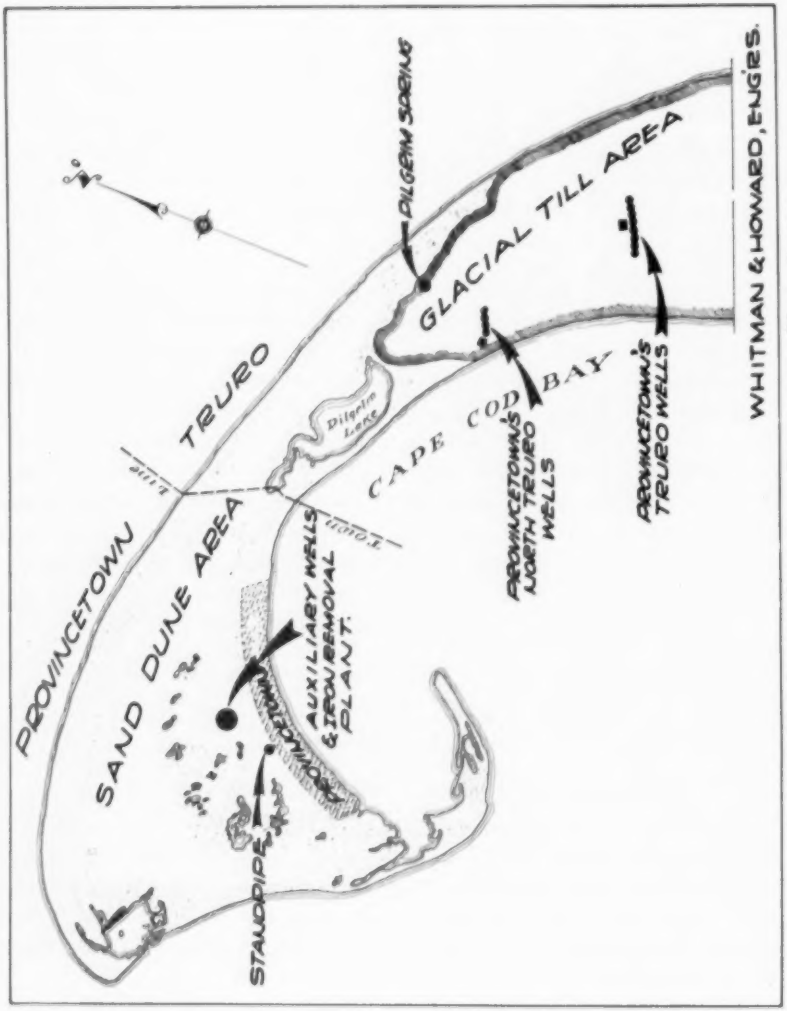

PLATE 1.—MAP SHOWING LOCATION OF PROVINCETOWN WATER SUPPLY.

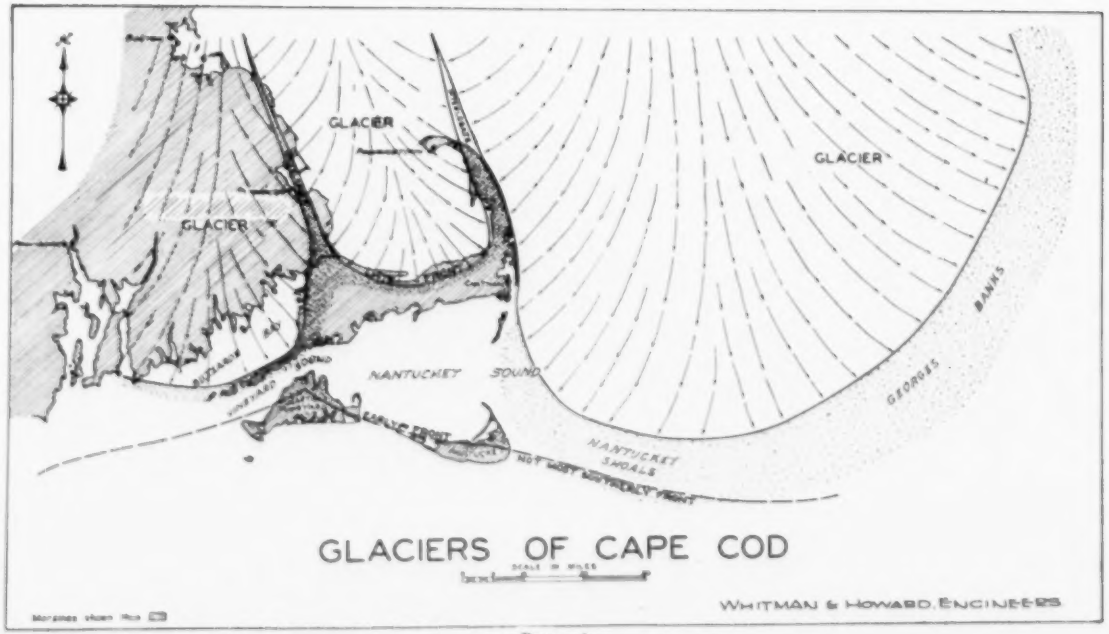
GLACIER
GLACIER
GLACIER
NANTUCKET SOUND
NANTUCKET SHOALS
GEORGES BANKS
GLACIERS OF CAPE COD
WHITMAN & HOWARD, ENGINEERS

PLATE 2.

water level and high water consumption. This high suction lift precluded the use of the ordinary horizontal centrifugal pump. A deep-well turbine-type pump was installed in a small concrete pit, extending 13 ft below the pump-room floor (see Plate 3). The existing sand chamber, situated at about the level of the pumping-station floor, was used for a combined vacuum and sand chamber. The bottom bowl of the turbine pump was placed about 10 ft below the pump-room floor, so that when the suction lift in the vacuum chamber measured 27 ft, it measured only 17 ft on the lowest bowl of the pump.

The system is first primed by means of an electric-motor-driven vacuum pump, which exhausts the air from the vacuum tank, thereby priming the system. When the diesel engine, which drives the turbine pump through a right-angle gear, is started, a vacuum pump, which is belt-driven from the diesel engine, also starts and keeps the system primed at all times while water is being pumped. The vacuum in the tank is controlled between limits by means of an automatic vacuum breaker.

During the summertime there is an extensive and variable draft, due to the many water connections to the five-mile-long supply main from North Truro to Provincetown. There are also hydrants connected with this main. The changes in draft and the operation of hydrants change the head pressure on the pump and, of course, a broken main could greatly lower this head pressure.

Since the discharge of a turbine-type pump varies greatly with the head that it is pumping against, it was found that, although the diesel engine driving the pump was set for a constant speed, the yield of the pump would vary greatly and, at periods of low-head conditions, the draft on the 2½-inch pipe wells would become excessive; furthermore, the level of the water in the ground at the wells would reach such a low level as to allow the underlying salt water to rise up and enter the wells. This has actually happened several times in years gone by. Although the diesel engine is normally a constant-speed machine, it was desired to find a way to vary satisfactorily the speed of the engine, in order to maintain a constant rate of discharge from the pump, irrespective of the total dynamic head on the pump. With the aid of the Foxboro Co. this was accomplished. They built an

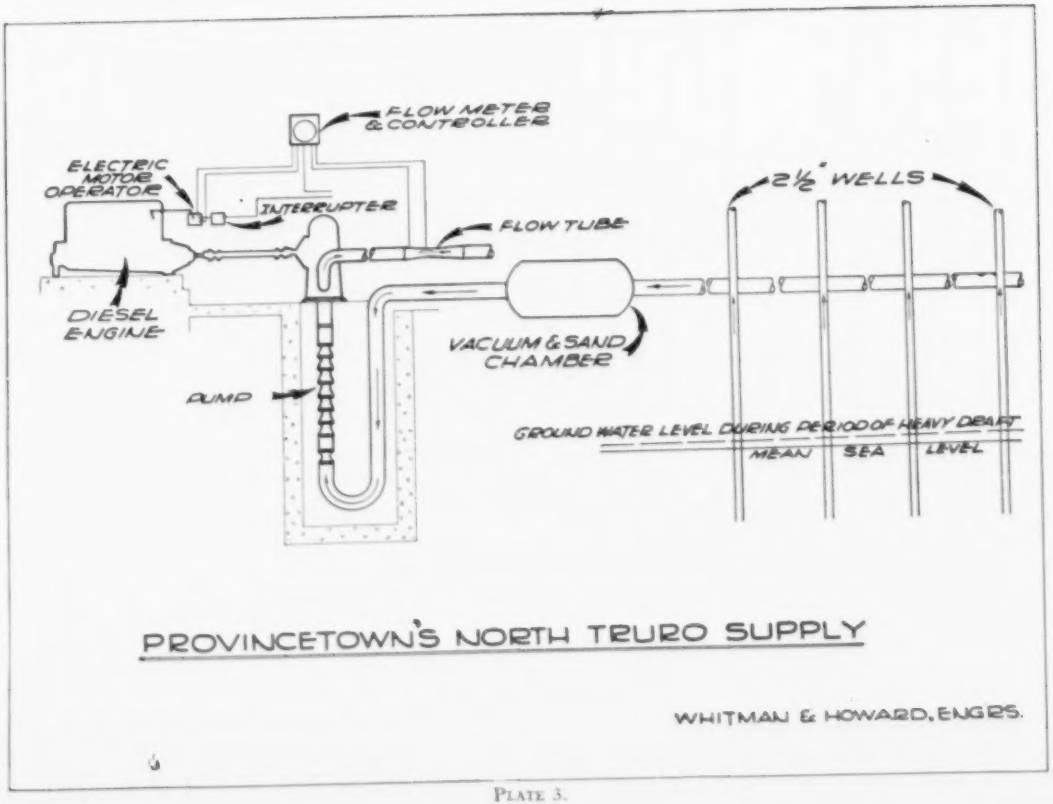
FLOW METER & CONTROLLER
ELECTRIC MOTOR OPERATOR
INTERRUPTER
FLOW TUBE
2½" WELLS
DIESEL ENGINE
VACUUM & SAND CHAMBER
PUMP
GROUND WATER LEVEL DURING PERIOD OF HEAVY DRAFT
MEAN SEA LEVEL
PROVINCETOWN'S NORTH TRURO SUPPLY
WHITMAN & HOWARD, ENGRS.

PLATE 3.

electrically operated controller, which is sensitive to the differences in head produced on each side of the orifice used to determine the rate of pumping as the rates of flow vary. This controller, in turn, operates a motor connected to the speed control of the Caterpillar diesel engine. The controller, attached to the flow meter, can be very readily set for any desired rate of pumping and the speed of the diesel engine is automatically varied, thus controlling the rate of pumping within very close limits. The normal rate of pumping is 600 gal per min.

Provincetown's Water Supply from Truro

In 1951 it became evident that due to the rapid growth of the town, the water supply of 600 gpm from North Truro and 300 gpm from the auxiliary supply in Provincetown would not be sufficient to meet the immediate future peak requirements of the town. Test wells were driven in Truro along South Hollow Rd., at a location about seven miles from the business center of Provincetown. These wells were driven in a valley, where the melt ice from the glaciers had sorted the material as the streams flowed from the glacier toward Cape Cod Bay. It was found that the sand was so uniform and coarse that it did not offer much resistance to flow and that the normal ground-water level was only 5½ ft above mean sea level, or about one foot above mean high water in Cape Cod Bay. In order not to depress the ground-water level, while pumping at a rate of 800 gpm, below an elevation about two feet above mean sea level, it was found necessary to install eight gravel-packed wells in a line, 950 ft long. Each well was built of 8-inch wrought-iron casing with 8-inch well screen 10 ft long; a 12-inch temporary casing was driven, and the area between the 8-inch screen and the 12-inch casing was filled with selected gravel before removing the 12-inch casing. Since the normal ground-water level varied from 17 ft below the natural ground at one end of the well field to 24 ft at the other end of the well field, a large, permanent trench was excavated and the 8-inch suction main, connecting the wells to the pumping station, was buried in this trench with 5 ft of earth cover. A pumping station was built at a low level, so that the water could be pumped by means of the usual horizontal, centrifugal pump with vacuum system, all driven by a diesel engine (see Plate 4). Although there are neither hydrants nor serv-

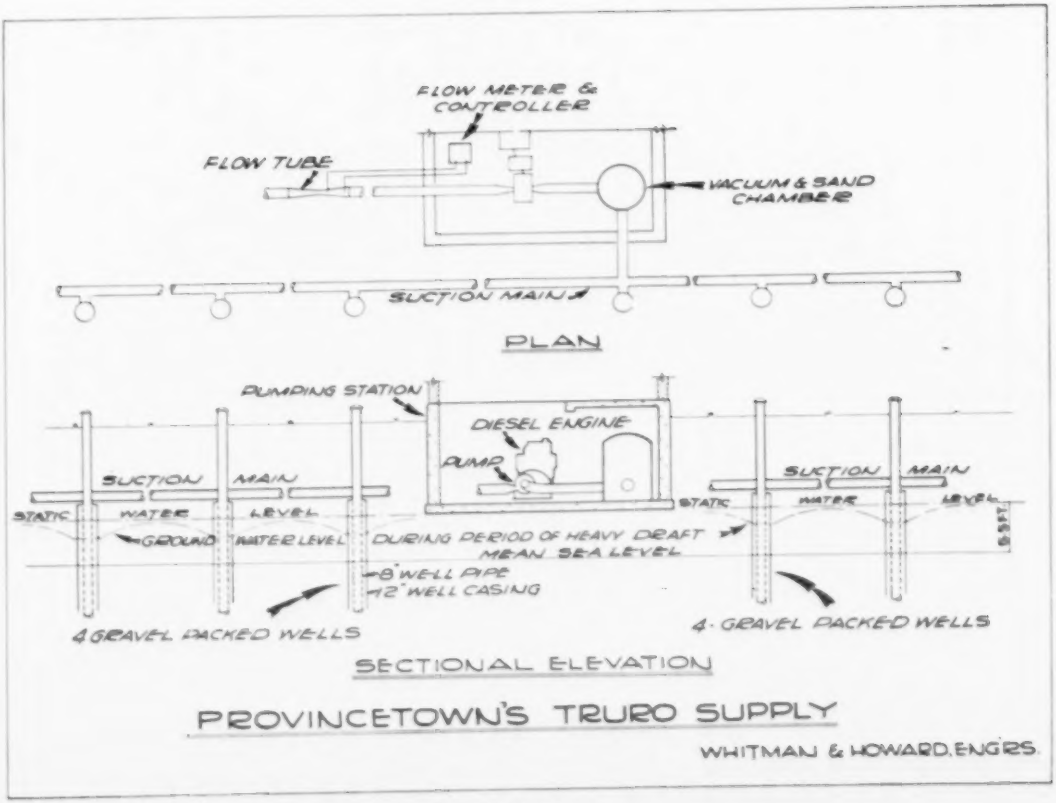
FLOW METER & CONTROLLER
FLOW TUBE
VACUUM & SAND CHAMBER
SUCTION MAIN
PLAN
PUMPING STATION
DIESEL ENGINE
PUMP
SUCTION MAIN
STATIC WATER LEVEL
GROUND WATER LEVEL
DURING PERIOD OF HEAVY DRAFT
MEAN SEA LEVEL
8" WELL PIPE
12" WELL CASING
4 GRAVEL PACKED WELLS
4 GRAVEL PACKED WELLS
SECTIONAL ELEVATION
PROVINCETOWN'S TRURO SUPPLY
WHITMAN & HOWARD, ENGRS.

PLATE 4.

ices connected with the new supply line, leading from the Truro pumping station to Provincetown, that would materially vary the head on the pump, there is always the danger that, in case of break in the pipe, the head on the centrifugal pump would drop materially and result in over-pumping the wells.

A flow meter and controller were installed in this station in a manner similar to the unit installed at the North Truro station, which automatically maintains a constant rate of pumping, irrespective of the head condition. Normal operation is for the operator to start the diesel engine in the early morning hours, as required, and to set the controller for the desired rate of pumping. The pumping unit is then left unattended until the late evening hours, when the water demand has diminished and can be met by pumping from the North Truro supply. Protective devices were installed, to shut down the unit in case of low oil pressure, overheating of cooling water, etc. The vacuum priming system is similar to the one installed at the North Truro pumping station.

The type of controller described was used in order to keep the cost of pumping at a minimum. Had the usual type of rate-of-flow controller valve been installed, the flow would have been controlled by throttling the discharge, thus adding unnecessary head on the pump. This method, which is the equivalent of partially closing a valve on the discharge side of the pump, is expensive in that it wastes a great deal of power.

Centerville-Osterville Fire District

Test wells for the Centerville-Osterville Fire District, installed at Route 28, showed the formation to consist of very fine sand that was water-bearing and capable of yielding about 1 mgd. In fact, one well would yield 1 mgd, but the finer particles of sand could not be held back when pumping at this rate. It was determined that if the rate per day was dropped to one-third mil gal, the material used to pack the wells could be small enough to prevent the natural sand from entering the well. Therefore, it was decided to build three gravel-packed wells. However, since the cost of building three pumping plants would have been excessive, it was decided to install one diesel-engine-driven, turbine pumping unit, which the District owned, at the middle well

and to lay suction main from the casing of this middle well to each of the other wells. This suction main is airtight and connected by welding to each well casing. A vacuum priming pump, driven by belt off of the diesel engine, is connected by a pipe to the top of the casing of the well housing the turbine pump (see Plate 5). A vacuum breaker, attached to this vacuum pumping unit, automatically controls the vacuum and maintains the proper water level, causing the water from the two outlying wells to flow upward and through the suction mains to the pumping well, where the water flows downward between the casing and the pump column to the pump intake. This arrangement has proven to be very satisfactory.

Each well was pumped individually and its specific yield (gallons per foot of drawdown) was determined. The differences in elevation between the static water level and the water level as observed in each well while drafting from all three wells was also determined. From these measurements it was found that the well containing the pump yields 340 gpm; one outlying well yields 218 gpm, and the other 148 gpm. During the pumping test no sand was observed in the discharged water.

When pumping at the rate of 1 mgd from these wells, the water level at the wells drops below mean sea level. Although these wells are located on Cape Cod, about one-half mile from tide water, it is not expected that there will be any entrance of salt water into the wells. It is generally believed that salt water underlies the fresh ground water of Cape Cod. However, in the Centerville-Osterville area the underlying material below the bottom of the wells is a so-called "clay sand", offering great resistance to the flow of water through it. In fact, it is almost impervious, thus preventing the salt water from rising up through it. These wells are used only during periods of peak demand in the summertime, so that the total quantity of water removed is not sufficient to allow the salt water to flow through the coarser aquifer longitudinally a half-mile to the wells.

Size of Pack for Gravel-Packed Well

It is usual to fill the area between the temporary outer steel casing, used when making the excavation for a gravel-packed well, and the well screen and permanent well casing with selected gravel

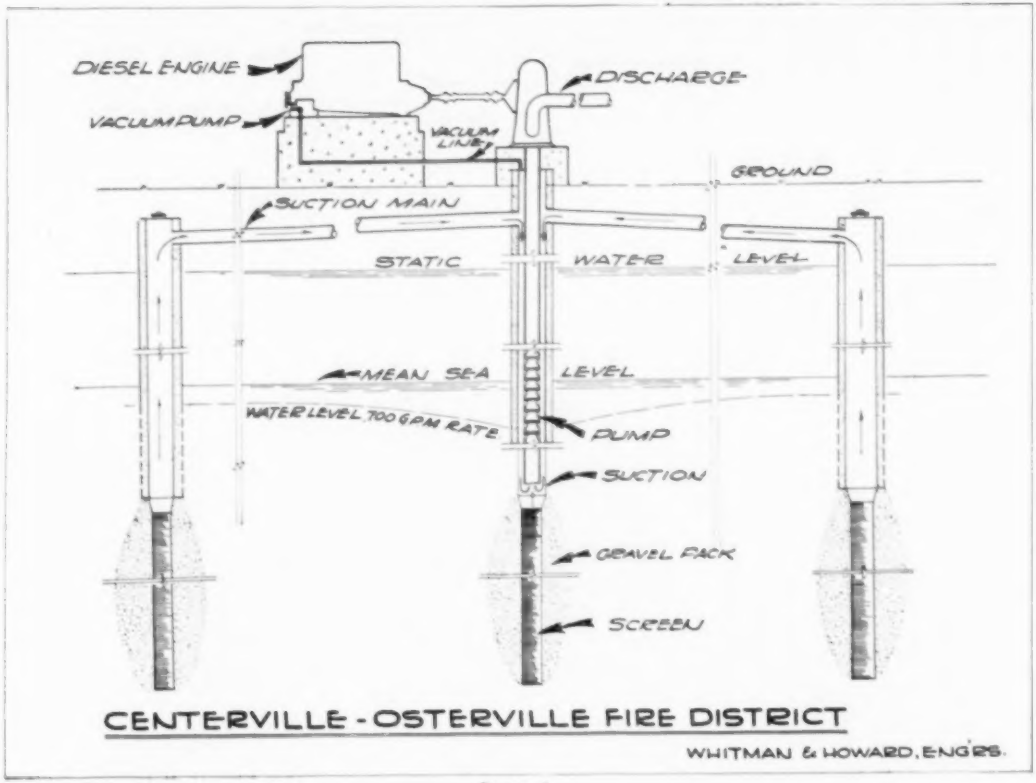
DIESEL ENGINE
DISCHARGE
VACUUM PUMP
VACUUM LINE
GROUND
SUCTION MAIN
STATIC
WATER
LEVEL
MEAN SEA
LEVEL
WATER LEVEL 700 GPM RATE
PUMP
SUCTION
GRAVEL PACK
SCREEN
CENTERVILLE - OSTERVILLE FIRE DISTRICT
WHITMAN & HOWARD, ENGRS.

PLATE 5.

and sometimes sand. This is done primarily to hold back the sand and gravel of the natural formation from entering the well, after the temporary casings have been removed and the well is being pumped. From time to time, particularly when fine material has been encountered in the natural formation, sand has passed through the pack into the well and has been pumped into the distribution system.

Considerable investigation has been made by us and others to determine the size and method of packing these wells, in order to prevent sand from entering them when they are being pumped under normal operating conditions. It has been found that control can best be obtained by determining the 50% size of the sand or gravel particles, both in the natural formation and in the material used for packing. By the usual method of sieve analysis, samples of all materials encountered and materials used for the pack are graded. The 50% size of each sample is determined by finding the size of particle of which 50% of the sample by weight has larger particle sizes and, likewise, 50% has smaller particle sizes. The 50% particle size appears to be a significant size and a size by which one can judge the ability of the particles to arch or bridge. Plate 6 shows the natural formation encountered in a recently constructed gravel-packed well and the method used to determine the size of the pack.

If the material used in packing is very fine, it will, of course, reduce the flow into the well. However, if the material used to pack the well is larger, it will increase the flow to the well, but allow sand particles to enter the well. Therefore, limits must be set.

In general, we have set the limits for the 50% size of the material used to pack the wells next to the natural formation at not less than three times nor more than five times the 50% size of the material in the natural formation. Likewise, for the material used in packing the well next to the screen and permanent well casing, the limits set shall bear the same relationship to the pack as used next to the natural formation. For example, with reference to Plate 6, the natural formation, consisting of fine to medium sand, brown in color, that was encountered between depths of 43 ft and 49 ft 6 in. was found to have a 50% size of 0.30 mm; therefore, the 50% size of the material to be used for packing next to the natural formation could be from 0.9 mm to 1.5 mm and the size next to the screen could

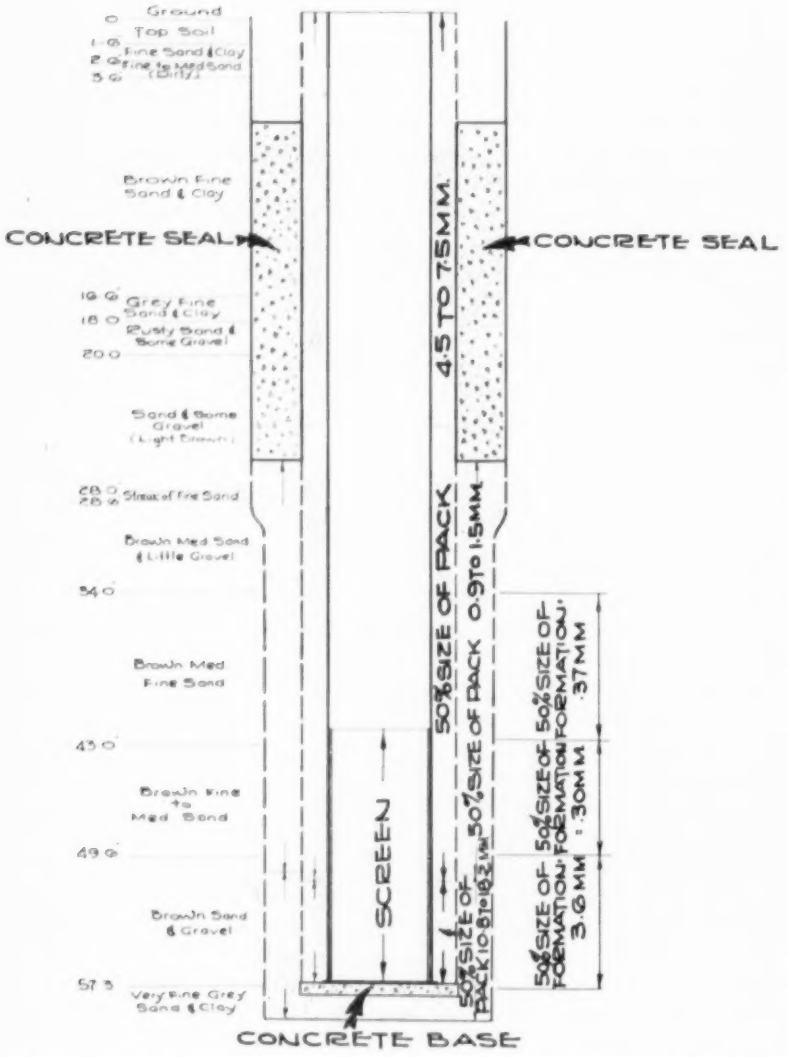

PLATE 6.—SIZE OF PACK FOR GRAVEL-PACKED WELL (WHITMAN & HOWARD, ENG'RS.)

be from 4.5 to 7.5 mm. (There are approximately 3 mm to ⅛ of an inch.)

There is, however, another factor that has to be given serious consideration when designing such a well and that is the rate at which the well is to be normally pumped, as the velocity of the water through the natural formation and pack varies directly with the rate of pumping; and, of course, the higher the velocity, the larger the size of the sand and gravel particles that will be moved by it. We are now correlating data in an effort to determine safe velocities for various sizes of materials encountered.

NEW ASPHALT-LINED RESERVOIR FOR RUTLAND, VERMONT

BY EDWARD L. TRACY*

[*Read January 20, 1955.*]

This paper describes the new Rutland water-supply reservoir, particularly the lining which was considered necessary because of the nature of the soil at the site. The 85-mil gal reservoir, with connecting pipe lines, was put into service in November, 1954, by the city of Rutland. It is believed that this relatively new type of reservoir construction will be of interest to the members of the New England Water Works Association and may be of value to some engineers and water superintendents who are planning water-storage facilities.

It is not intended here to go extensively into the history of the Rutland water system, but a brief review will show the long years of planning that were finally climaxed by a well executed program of promotion and accomplishment.

Rutland is located in west central Vermont at the junction of routes US-7 and US-4. With a population of a little over 18,000, it is Vermont's second city. The watershed area of 25 square miles is on the western slope of the Green Mountains, east of Rutland. Spring-fed mountain brooks, from this basin converge into Mendon Brook, which flows west near US-4 and passes north of the city.

The supply system, which takes water from Mendon Brook, has been in the present location northeast of the city since 1876. At that time, an infiltration gallery was built and a 12-inch pipe laid to the community a little over three miles away. This "filter gallery" is described in the book, "Quest for Pure Water", by M. N. Baker. This original system was designed by Percy Blake.

In 1879 a new distribution system was installed in the village. By 1880 the infiltration gallery was inadequate and water was taken directly from Mendon Brook through an open channel to two 1-mil gal reservoirs.

*Chief, Bureau of Environmental Sanitation, Vermont Department of Health, Burlington, Vt.

In 1892, a year after Rutland had become a city, a 5-mil gal reservoir was constructed and a 16-inch pipe laid parallel to the 12-inch line to the city. This was the end of major construction on the water-supply system until 1953, sixty-one years later.

During this interval, chlorination was started in 1912 with chloride of lime and in 1915 with chlorine gas. A venturi meter was installed in 1930 below the 5-mil gal reservoir. The natural watershed area was artificially increased in 1914 by diverting the north branch of Cold River at the south end of the Mendon Brook drainage basin.

Comments on deficiencies in water quantity or quality began about 1904, when the reservoir was only twelve years old. In 1908 a survey and report were made by George Whipple, but no action was taken on his recommendations for enlarging the supply. In 1912 Barrows and Breed submitted a report, which recommended a new storage reservoir on the Davis farm, in a natural basin about 1,200 ft southeast of the existing 5-mil gal reservoir. This is the site of the new 1954 reservoir. In 1912, however, there was much doubt about the advisability of this location, as the average person believed the fine sandy soil to be too porous for a reservoir location.

No more definite proposals were put forth until 1938, when a large storage reservoir was recommended on Mendon Brook, about 3½ miles upstream from the existing reservoir. This was a good location for water storage and was designed as a federal-aid project with a maximum of hand labor, as was the custom during the depression years 1933 to 1938. The disadvantage of the location was the long pipeline needed to connect with the existing water system. The city vote on the project failed to get the necessary two-thirds majority for bond-issue construction. At the same time, before the 1938 vote, the so-called Davis site, recommended by Barrows and Breed, was again considered. Because of the relatively high materials costs of a concrete lining, as compared with the labor costs, the project was not then considered favorable.

The upstream Mendon Brook storage reservoir was voted on again in 1940, twice more in 1949, and for the last time in March, 1950, when the project did not get even a simple majority. It appeared that the water-supply question was completely worn out by repeated unsuccessful voting, but in 1950 the Chamber of Commerce

organized a citizens' study committee, headed by a Rutland utilities engineer, Harold Durgin.

In August, 1951, this committee submitted a report, recommending the construction of an 80-mil gal reservoir at the Davis site for about $350,000. Prior to the release of their report, in the spring of 1951, consideration was first given to lining the proposed reservoir with asphalt. At that time, articles were appearing in engineering and trade journals about asphalt-membrane lining for irrigation canals in Wyoming, built under the supervision of the Bureau of Reclamation. Technical development on this type of reservoir lining was promoted by the Asphalt Institute.

The proposed reservoir was intended to correct the shortcomings and objectionable features of the old water system. The size was intended to be sufficient, with the normal flow of Mendon Brook, to provide adequate quantity of water for domestic and industrial use and fire protection. Excessive turbidity had been experienced at times since 1891, because the 5-mil gal reservoir was too small to accomplish proper sedimentation. This would be corrected by the new reservoir. Objectionable chlorine-combination tastes, due to varying organic content of Mendon Brook water, would be eliminated by longer sedimentation of the water before chlorinating. The proposed location would be safe from flood damage, of which Rutland residents were very conscious after 1947. The higher location of the proposed reservoir would provide increased pressure in the city. The reservoir location is easily adapted to future expansion.

A final report, confirming the above proposals, was submitted in December, 1952, and when voted on in March, 1953, the project was approved by a 3-1 vote ratio. Whitman & Howard, Consulting Engineers, Boston, had been retained by the city, and plans were completed and construction was started by M. J. Burrington, Jr., Construction Engineer, Bennington, Vt., in August, 1953.

The construction plans developed by Whitman & Howard accomplished the objectives outlined in the Chamber of Commerce committee report. The reservoir, as designed, takes full advantage of the natural basin at the Davis site. It is located south of Mendon Brook about 1,500 ft. The water supply is taken from Mendon Brook, a little over one-half mile above, or northeast, of the reservoir, by a low

concrete dam, having a crest length of 40 ft. From here water flows through 1,909 ft of 20-inch pipe, then 1,450 ft of 16-inch pipe—a total of 3,359 ft—to the discharge into the east end of the reservoir. The water surface of the reservoir, when full, is at elevation 925. The surface area is 598,000 sq ft or 13.7 acres, at that elevation. The length of the reservoir is about 1,300 ft and the maximum width is about 800 ft.

The dam, at the west end of the reservoir, is 355 ft long at the top. It is 42.5 ft high, above the natural ground level, at the center and 210 ft wide at the bottom, measured along the natural ground surface. The slope of the upstream face is 2½ on 1 and the downstream face is 2 on 1. The dam has a concrete core wall. There are two 16-inch pipes through the base of the dam. One is a waste pipe, with its upper end, east of the gate chamber, at elevation 887 and the outlet end, at the downstream toe of the dam, at elevation 880. The water depth at the waste-pipe upper end is 38 ft when the reservoir is full.

A 6-inch tile-pipe sub-drain extends across the downstream face of the core wall above the footing. This is about one foot below the original ground surface near the center of the core wall and is from eight to ten feet below the old ground surface toward the ends of the dam. An outlet drain pipe extends out beyond the toe of the downstream embankment and discharges at elevation 882. This sub-drain will not only keep the embankment fill drained but will detect any seepage, if such is possible.

The low intake to the gate chamber is through a 16-inch pipe at elevation 891, or 34 ft below the water surface. The intake rack openings in the gate chamber are at elevation 906, 19 ft deep, and at 920, 5 ft deep. The top of the gate chamber is at elevation 930. The top of the dam is 930.5.

There is no spillway or overflow at the dam. There is a 20-inch, morning-glory-type, overflow pipe in the dike section at the northern side of the reservoir. The flow to the reservoir is controlled at the Mendon Brook intake so that the reservoir is kept full and overflowing a small amount through the pipe at this dike.

A 16-inch, mechanical-joint, Class 250 pipe was installed from the gate structure to the toe of the dam. From the end of this

pipe, a 20-inch pipeline extends 4,619 ft to the 1891, 16-inch pipe to the city. Here there is also a 12-inch pipe, 112 ft long, connecting the 16-inch main with the 1876, 12-inch pipe.

A new chlorine and meter house is located about one-quarter of the way between the pipe-junction point and the city. This brick building has a room for chlorine gas cylinders and a room for two chlorinators, one of which is in reserve. In a third room in rear is the flow recorder, which is connected to the 16-inch orifice-plate meter, located underground in front of the chlorine and meter house. In the basement are the heater, pressure-regulating valves and chlorinator water-booster pumps. An auxiliary water-driven pump assures continuous automatic operation of the chlorinator if electric service is interrupted. A pressure-reducing station is located just northeast of the city. It was necessary to install pressure-reducing valves as the distribution system contains much Class B, pit-cast, iron pipe. These valves have eliminated most of the former daily fluctuations in pressure.

The construction of the dam did not present any unusual features that warranted attention from the State Department of Health. Our active interest in the construction procedure began when the reservoir basin was being readied for the lining, early in the summer of 1954. The specifications of Whitman & Howard required the removal of a minimum of 8 in. of sod and loam from the entire 67,000 sq yd of basin surface. All trees, stumps and large roots were removed. The subgrade was dragged, to produce a surface free of abrupt breaks, protruding stones, sticks, roots, etc. The entire surface was then raked by hand with iron garden rakes, to remove all stones. This fine surface was then rolled. It was sprinkled with water just before the asphalt was applied, so that the liquid asphalt would not ball up. The asphalt was applied at the rate of 2 gal per sq yd, giving a minimum thickness of 0.2 in. The specifications required that the completed asphalt lining must be free from thin areas and holes. The membrane thickness was built up by two or three separate applications, particularly on the slopes where there might be a tendency to flow. Separate applications also insure against pin-holes in the finished membrane. A covering of 12 in. of sand and gravel, with no large stones, was spread over the entire completed asphalt membrane.

On the upstream face of the dam an additional stone rip-rap, 12 in. thick, was placed.

The asphalt used to form the membrane is a special product, modified by processing so that when spread it gives a tough, flexible and durable film. The modifying process gives an asphalt of lower temperature susceptibility; in other words, one that will remain flexible at low temperatures and will not soften rapidly at high temperatures. The modifying process also improves the ductility of the asphalt, so that the film will stretch or give under stress, without rupturing. If the subsurface under the asphalt settles unevenly, the membrane will stretch, rather than crack or break.

The specifications of Whitman & Howard required the flash point of the asphalt to be at least 425° F. and the softening point to be 175° to 200° F. The loss at 325° F. could not be more than 1% in 5 hours. The bitumen content had to be at least 97%. This asphalt differs from road asphalt in that it does not penetrate the dirt sub-surface, but remains on the surface as a sheet or membrane. The application temperature, about 400° F, is much higher than for road asphalt. Unless this high temperature is maintained at the distributor truck, the hose will "freeze" or clog.

The completed 85-mil gal reservoir will provide ample storage of water even though the daily per-capita water use in Rutland is excessive. In 1950, when the population was about 18,000, the average daily water flow to the city was 3.4-mil gal or 188 gal per capita. If the flow of water into the new reservoir should be shut off at Mendon Brook, the stored water is theoretically adequate for 25 days. As the available flow of water in Mendon Brook rarely drops below 4 mgd during the most severe drought periods experienced, it appears certain that the new reservoir can take care of a reasonable industrial or population growth.

Since high rates of water use are common in Vermont, the daily use in Rutland should not be surprising. Even back in 1908, when the Whipple report was made, the average per-capita use of water in Rutland was 125 gal.

Of greatest interest to the State Department of Health, of course, is the quality of the water at the consumers' homes. During past years the bacteriological quality has been quite good, in view of the diffi-

culty of maintaining proper chlorine dosage for varying conditions of the Mendon Brook water. The following tabulation shows the results of analyses made by the State Department of Health:

Year	Number of samples	Portions analyzed	Portions contaminated	Percentage contamination
1953	358	1,790	38	2.1%
1952	320	1,600	50	3.1%
1951	315	1,575	74	4.7%
1950	304	1,520	28	1.8%
1949	317	1,585	14	0.9%
1948	305	1,525	61	4.0%
1947	386	1,930	40	2.1%
1946	318	1,590	27	1.7%
1945	335	1,675	41	2.4%
1944	330	1,650	34	2.1%
Total and Average	3,288	16,440	409	2.5%

These analyses were made in accordance with Standard Methods of Water Analysis. From each sample, five portions of 10 ml each are examined.

Mendon Brook water, when not turbid from heavy runoff, has a favorable chemical analysis, as shown by the following tabulation.

The principal improvement noted in the water from the new reservoir so far is a substantial reduction in color, albuminoid nitrogen and ammonia nitrogen. It is too soon to report completely on organic-content improvement. During the filling process, the water became turbid in appearance from the layer of sand and gravel over the asphalt membrane. This turbidity settled out in a reasonable time. It is expected that chlorine-combination tastes will not be detectable in the future in the distribution system. The Rutland Commissioner of Public Works reports that he already has received many favorable comments on improved water quality.

The State Department will make periodic analyses of the water, so that data will be available to show the anticipated benefits of sedimentation. For the first time, Rutland will be using water that has had a reasonably long sedimentation period. A comprehensive long-

	MENDON BROOK			NEW RESERVOIR				
	1952 average	1954 average	12/3/54	Inlet E. end 10/15/54	Outlet W. end 10/15/54	Outlet 12/3/54	City tap 12/3/54	Chlorine house 1/10/55
Turbidity	V.S.	V.S.	Slight	V.S.	V.S.	V.S.	0	0
Sediment	0	0	0	V.S.	V.S.	0	0	0
Color	10	22	5	20	15	5	5	5
Odor	0	0	1D	0	0	0	0	0
pH	7.4	7.6	7.2	7.8	7.7	7.2	7.2	7.1
Hardness	41	29	30	42	38	33	32	29
Chlorides	2.3	3.0	1.5	3.1	2.4	2.5	4.2	5.3
Albuminoid	0.046	0.064	0.060	0.054	0.078	0.102	0.066	0.000
Ammonia	0.004	0.000	0.000	0.012	0.012	0.012	0.000	0.000
Nitrite	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nitrate	0.27	0.07	0.3	0.0	0.0	0.1	0.1	0.3
Total Alkalinity	28							13.8
Total Solids	104							78
Ca	24							7
Mg	20							22
Fe	0.0							0.0
CO_2	2.6							3.2
Coliform M.P.N.	23	27		9.2	2.2		0	0

range study of coliform-organisms content will be made, to observe the effect of long sedimentation on coliform count. The sub-drain will be watched, to record whether any seepage takes place.

The City Engineer and Commissioner of Public Works of the city of Rutland is Edward Crowley. The Mayor is Daniel J. Healy. The engineer in charge for Whitman & Howard was Roger Disken and the resident engineer during construction was Ralph E. Beck. The asphalt was furnished by Socony-Vacuum Oil Co., for which C. A. Van De Carr is district representative and Gorman Bros. were application sub-contractors. As stated before, the general contractor was M. J. Burrington, Jr. The pipeline sub-contractor was Joseph Carrara.

MAINTENANCE OF STEEL WATER-WORKS TANKS

BY GEORGE A. SAMPSON*

[Read February 17, 1955.]

As an introduction to the problem of maintenance of steel water-works tanks, the speaker will first list the specifications and recommended practices available in printed form and then briefly summarize the conclusions contained in these documents.

SPECIFICATIONS

The American Water Works Association Journal for November, 1935, contains specifications entitled "Standard Specifications for Riveted Steel Elevated Tanks and Standpipes", prepared by a committee of that association. Following the advent of welding construction, a joint committee of the American Water Works Association and the American Welding Society revised these specifications to include welding and they were approved by the New England Water Works Association on September 24, 1942.

In October, 1944, the NEWWA appointed a committee on "Steel Standpipes and Elevated Tanks", to serve as a joint standing committee with representatives of the AWWA and the AWS. This joint committee proceeded to revise the 1942 specifications and the revisions were approved by the NEWWA on September 14, 1948. These revised specifications were entitled "Standard Specifications for Elevated Steel Water Tanks, Standpipes, and Reservoirs" and were published in the December, 1948, JOURNAL. The committee also prepared separate recommendations for repairing and repainting existing tanks, as distinguished from new tanks, under the title, "Tentative Recommended Practice for Inspecting, Repairing and Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs". This document was also approved by the NEWWA on September 14, 1948, and published in the December, 1948, JOURNAL.

After further study, the joint committee revised the 1948 specifica-

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tions under the following three separate headings: "Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs"; "Tentative Recommended Practice for Inspecting and Repairing Elevated Steel Water Storage Tanks, Standpipes and Reservoirs"; and "Painting and Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs". These three specifications were approved by the NEWWA on March 20, 1952, and the painting specification was published in the December, 1952, JOURNAL. The specifications have been printed in pamphlet form by the AWWA as D 100-52, D 101-52 and D 102-52, respectively, and are available for a nominal price at 521 Fifth Ave., New York 17, N. Y.

Additions and revisions are being considered from time to time and the committee would be glad to receive suggestions. The NEWWA representatives are Herman Burgi, Jr., Joseph C. Lawler and the speaker.

The proper maintenance of a steel water tank is concerned with periodic inspections, to determine the condition of the tank, repairs as needed to keep the tank structurally intact, and painting to protect the steel. Tanks need repainting frequently, but, if properly maintained, repairs are rarely necessary.

INSPECTION

Every steel water tank should be carefully inspected when leakage or some other apparent deterioration is observed as well as before repainting. In any event, all water tanks should be inspected at intervals of not more than five years. The owner should have a disinterested inspector examine the metal surfaces inside and outside, to determine the condition of the paint and metal, in order to decide what repairs, if any, are needed and what painting should be done. At the same time the owner should invite any contractors whom he wishes to bid on the work to inspect the tank and familiarize themselves with the actual conditions. The tank should be emptied and the inside surfaces thoroughly cleaned for the inspection. The owner should draw up proposals for the work to be done, covering any repairs, method of cleaning the steel, the kinds of inside and outside paint to be used, number of coats and other details.

Repairs

The owner, using the inspector's report as a guide, should define and list the repairs to be made. Contractors should be asked to submit bids on a fixed lump-sum or unit-price basis. The owner should itemize repair work by units, such as the number of rivets to be replaced, caulked or welded, the lineal feet of seams to be caulked or welded, the number of pits to be filled, any parts to be replaced, and so forth. All welding should be performed in accordance with the welding provisions given in AWWA-NEWWA-AWS "Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs", AWWA D 100-52.

All repairs shall be neatly done by experienced workmen using equipment best adapted to the work. Upon completion of the repair work the tank shall be watertight.

Cleaning Steel Before Painting

The methods favored for removing the mill scale from plates and structural shapes in the shop before applying a priming coat of paint are sand- or grit-blasting and pickling. If the purchaser specifies that mill scale be removed and if pickling or blasting is not specified, it shall be understood that only loose mill scale and rust be removed by wire-brushing, or the plates and structural shapes may be dehydrated in the shop with an oxy-acetylene torch, removing such mill scale as becomes loosened with one application of the torch followed by wire brushing, after which the priming coat shall be applied while the parts are still warm.

Paints

The committee's recommendations for paints and methods of painting are necessarily rather general in character, leaving the details to be set forth in the owner's specifications, which should describe the method of cleaning the steel, the kinds of paints, the number of coats both inside and outside. The specifications recognize that various types and kinds of paint have demonstrated their suitability and that no type or kind is universally applicable.

In repainting old tanks, if the paint is in good condition and adheres tightly to the steel, it may be left on. All rust, loose mill

scale and loose paint should be removed by means of sand- or grit-blasting, power-driven scaling tools, scrapers and wire brushes (preferably power-driven), emery cloth or sand paper and either air or cloth dusters. When cleaned by sand- or grit-blasting, the equipment should have ample capacity to furnish the required volume of compressed air to operate the blast effectively. If sand is used, it should be principally composed of silica grains and as coarse as is practicable to use. Special care should be used to clean around rivet heads, along seams and in pits. Whenever metal is cleaned by blasting on any day, it should be coated with a primer on the same day. If rust forms on any blasted surface, the surface should be re-cleaned and wiped free of dust before applying the primer. The metal should be completely dry before applying any paint.

The shop priming coat should be an inhibitive paint on all surfaces inside and outside, except on contact surfaces and along edges to be welded. It is important that the primer be compatible with the field coats of paint and desirable that the shop and field coats be made by the same manufacturer, to avoid subsequent irresponsibility.

The following paints are suggested:

Inside Surfaces

a. Red lead and linseed oil primer, conforming to Federal Specifications TT-P-86a, Type I, with the addition of 2 lb per gallon of dry litharge, to be added shortly before application, to speed up the drying. The paint shall set to touch in not more than 6 hours and dry through in not more than 24 hours. Each coat of paint shall dry for at least 24 hours before applying subsequent coats and the final coat shall dry for at least 48 hours before the tank is filled with water. The paint shall show no curdling, caking or color separation and shall be free from lumps and skins. The paint shall brush easily and show no running or sagging tendencies when applied to smooth steel vertical surfaces. The paint, when reduced with not more than 1 part by volume of mineral spirits (conforming to Federal Specifications TT-T-291, Grade I) to 8 parts by volume of paint, shall spray satisfactorily in all respects. The paint shall dry to a smooth uniform finish, free from roughness, unevenness or other surface imperfections.

b. Red lead phenolic resin varnish paint, when used as a primer, is suitable only on thoroughly cleaned surfaces obtained by pickling or blasting. For finish coats, it is suitable for surfaces cleaned by wire brushing. This paint should conform to Federal Specifications TT-P-86a, Type IV. The general properties as to brushing and spraying are similar to red lead and linseed oil paint. One difference is in a considerably quicker drying period, which has the advantage of being able to speed up the time required to fill the tank with water after it is drained for painting.

c. Hot-applied coal-tar enamel priming and coating materials shall meet the requirements of the latest revision of AWWA C 203 and C 204, standard specifications for coal-tar enamel protective coatings for steel water pipe.

d. Cold-applied coal-tar paint, prepared from coal-tar pitch, mineral filler and solvent, designated as CA-50, does not have the durability of hot-applied coal-tar enamel, but can be applied by brushing or spraying and can withstand cold temperatures better than hot-applied enamel. A minimum of three coats should be applied. This coating is not suitable for use in open-top tanks which would expose the coating to direct sunlight.

e. Wax-grease coatings may be either of the cold-application type or of the type adapted for hot application.

Outside Surfaces

a. Red lead and linseed oil paint is suitable for the outside priming and finish coats. The specifications are similar to those for inside surfaces, except no litharge is added. The drying period for each coat is set to touch in not more than 6 hours and dry through in not more than 36 hours. Each coat of paint shall dry for at least 36 hours before applying subsequent coats.

b. Red lead phenolic resin varnish paint when used as a primer or finish coat on outside surfaces, should follow the recommendations for similar paint on inside surfaces.

c. White linseed oil chalking or non-chalking type finish paint shall conform to Federal Specification TT-P-102, Class A and Class B, respectively. They are titanium, lead, zinc and oil exterior ready-

mixed white paints. The maximum drying time is 18 hours. The non-chalking type is usually tinted in light colors.

d. Black linseed oil finish paint shall conform to Federal Specification TT-P-61a. It is a carbon, red lead, mineral-extender and, if desired, iron oxide, linseed oil paint. The maximum drying time is 18 hours.

e. Aluminum finish paint shall consist of a varnish conforming to Federal Specifications TT-V-81b, Type II, Class B, and an aluminum pigment powder and paste conforming to Federal Specifications TT-A-468a, Type II, Class B. The maximum drying time is 18 hours.

f. Foliage green, linseed oil paint, in accordance with the formula used by the State of Maine Highway Commission, Bridge Division, is also suggested. The formula is given in the specifications. The maximum drying time is 20 hours.

Paints should be delivered in the original containers, marked with the name of the manufacturer, type and quantity. The various coats should have enough difference in color so that each successive coat will be properly covered. It is suggested that the final outside coat be from the same manufacturer's batch for uniformity in color.

Electric (cathodic) protection has frequently been used for protecting water-tank interiors below the flow line with satisfactory results when properly installed and maintained. Some difficulties have been encountered in cold climates and when the water is a poor conductor of electricity. For installations in new tanks, it is recommended that all submerged steel surfaces be painted, as by its electrical resistance, the paint reduces current requirements.

Painting

For new tanks the field coats follow the erection and testing for leakage, when water is available. For tanks that have received a shop priming coat, the exposed, unpainted interior and exterior surfaces should be wire brushed, wiped clean and given a spot coat of the same inhibitive primer as used in the shop, followed by the number of coats of paint of the make, types, and colors specified by the purchaser. For tanks without a shop coat, the mill scale should be removed by blasting or by power wire-brushing if loose from weathering.

For new or old tanks, surfaces should be painted immediately after cleaning. Surfaces should be thoroughly dry before painting and a sufficient interval should elapse between coats for the undercoat to harden properly. No painting should be done when the temperature is less than 40°F. and no paint should be applied during wet or foggy weather, or upon metal coated with frost. Painting should be done only by experienced workmen.

The two general methods of applying red lead or similar paints are brushing and spraying. More recently, rollers have been used for welded tanks with apparently good results.

If the paint is applied by brushing, each coat should be brushed on in one direction and then smoothed in the opposite direction, to produce a complete coverage and a uniform thickness.

If applied by spraying, suitable nozzles should be used and the air pressure on the container and atomizer should be within the proper range for good work. Care should be taken to prevent paint spatters on adjacent buildings or property, by spraying only on quiet days and when the wind is in a favorable direction.

Coal-tar enamels are applied in two coats. The primer should be evenly and carefully applied to avoid runs, festoons or other heavy accumulations. No coal-tar primer should be applied when the temperature of the steel is below 45°F., or when there is any moisture on the steel. After the primer is dry for two or three days, the final coat is a hot coal-tar enamel, applied with daubers. The pieces of coal-tar enamel should be heated in a suitable melting kettle with an adjustable intensity of flame, to maintain the temperature recommended by the manufacturer. The enamel as drawn from the melting kettle should be poured through a fine wire screen, to remove any foreign substances.

Cold-applied coal-tar paint appears in the container as a heavy-bodied paste-like material, which by stirring becomes liquid enough for painting. The first coat, applied directly to the steel without a primer, is usually brushed; subsequent coats are applied by brushing or spraying with pump-type equipment.

Wax-grease paints applied cold shall be thoroughly rubbed onto the clean dry metal with a stubby brush. The thickness of the coating shall be not less than 0.02 inch and not more than 0.03 inch. The

tank can be placed in service as soon as the coating is complete.

Wax-grease paints applied hot shall be applied to the clean dry metal by means of a spray apparatus, utilizing fluid pressure through special nozzles. The temperature of the coating shall be not less than 250°F. and not more than 300°F. After application the coating should be thoroughly flamed with a torch, to smooth out all laps and close any pinholes. The thickness of the coating shall be not less than 0.03 inch and not more than 0.06 inch.

Ventilation

Adequate ventilation must be provided while painting or coating the interior surface of a tank, especially with coal-tar products and some volatile paints. It is sometimes necessary to provide forced-air ventilation.

Cleanliness

All the operations of erecting, repairing and painting potable-water tanks should be conducted in a sanitary manner. No person shall be permitted to work in a tank if he has had a malignant illness within a period of 7 days prior to entering the tank. The purchaser shall have the right to engage a physician to judge whether any person is unfit to work in the tank.

The owner shall assure himself by a careful inspection that the interior of the tank is clean and sanitary before it is placed in service. In addition, it is recommended that the tank should be disinfected. For this purpose chlorine is usually used. A common method is to scatter high-test calcium hypochlorite (H.T.H.), either as a powder or liquid solution, over the bottom of the tank as it is filled with water, so as to provide a concentration of 50 ppm of chlorine in the full tank. Sometimes a lesser concentration is used when the chance of contamination is negligible. After the tank is filled, it should stand 24 hours if possible, but for not less than 6 hours, depending on whether any pollution may be protected by films or particles.

The tank should then be completely drained to waste and refilled from the regular source of supply. After filling, a sample of water should be collected and analyzed, to determine whether the tank may be safely placed in service.

THE SUPERINTENDENTS' PROBLEMS IN THE MAINTENANCE OF STEEL WATER-WORKS TANKS

BY ALLEN M. SYMONDS*

[Read February 17, 1933.]

The average water-works superintendent is employed in an occupation which is very much diversified. To cover all phases of his work he should be a construction engineer, a mechanic, an office manager, a public-relations expert, an orator and a steeple-jack. Most of us make out fairly well with all of these phases except the last one. If a pump breaks down or a pipe springs a leak or a customer argues about a water bill, we have in each case something tangible to work on or throw out the office door, as the case may be. When it comes to a standpipe or elevated tank we have something different. In my experience I do not know of a single water-works man who will climb to the top of a 100-foot tank.

Interruption of Fire Service

Another important factor having to do with the maintenance of water tanks is that many average-sized towns depend upon a single tank to furnish fire protection, with the result that there is a serious fire hazard when the tank is taken out of use. This is a responsibility which the water-works superintendent does not like, but must accept when he makes plans to paint his tank.

Speaking from the standpoint of a private water company I have often wondered as to the legal liability in case of a damaging fire, with little or no water available because of the water tank's being voluntarily taken out of service. In my experience I have not encountered any damage suit because of these conditions, but I can visualize my feelings if I happened to find myself on the short end, unprotected, and the result was the loss of a home. Such thoughts sometimes make you wonder whether or not the risk is worth while.

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Because of these problems water-tank maintenance is often neglected or deferred to some future date.

Confidence in Contractor

Due to the fact that climbing over and around tanks is a specialized occupation, performed only by steeple-jacks, the water-works superintendent is very much at the mercy of a contractor who may be awarded the maintenance work. For this reason, it is extremely important that he choose only a proven and reliable firm and cooperate with them to the fullest possible extent. In order to obtain the best and most efficient result, there must be complete understanding and harmony between the superintendent and the painting contractor. This is probably more important in tank work than in any other phase of the water-works business.

My past experience has brought me in contact with various types of contractors, one of whom I happened to catch applying two coats of paint on the same surface in one day, the second coat being applied during a thunderstorm. Needless to say, the contract expired right then. On the other hand, there are here in New England very responsible painting and maintenance contractors, who desire repeat business and who will co-operate 100%.

Cost of Work

The old axiom that "you get what you pay for" is probably more true in water-tank maintenance than in most other projects. This fact is accentuated because the maintenance man is beyond your sphere of operations. When he is swinging around in a boatswain's chair near the top of a 100-ft tank, you probably are not sitting beside him; he is working in a world of his own and you, under the circumstances, must have confidence in him. Because of the specialized nature of this occupation, it is quite logical that a premium be paid for this type of work and it will usually cost more to paint a tank than to paint a building several times its size. Bids for painting a ½-mil gal water tank can range all the way from $2,000.00 to $5,000.00 and it is often very difficult for the water-works superintendent to decide the issue. A "fly-by-night" contractor will take advantage of this situation and may submit a low bid, which is attrac-

tive at first thought, but in the long run will prove the most expensive.

Importance of Preliminary Inspection

On the assumption that you are dealing with reliable contractors, the cost of reconditioning a tank is pretty much in proportion to the amount of work to be done. This requires study on your part and necessarily an inspection of the tank, both inside and out. At this point a painting contractor who is in your confidence can be of real help.

Most of us realize that the preparation of a tank for painting is the most costly and painstaking part of the project. The coat of paint applied to a defective base is actually worse than nothing. It may look good for a few months, but will eventually have to be removed along with the defective base before the tank can be properly painted. It follows that the more material has to be removed, the more costly will be the work.

An inspection will usually reveal patches where the paint has failed, and the metal has become rusted and pitted, as well as the depth of the pitting. It will reveal blisters where the paint is still in place, but separated from the metal. In a riveted tank an inspection may reveal rivet heads on the inside rusted away, causing seepage. The inspection will reveal the types of coatings previously applied, principally on the inside. Many tanks have been painted with a hot tar or asphalt coating, which will require special treatment. Your inspection may reveal seepage through seams of a riveted tank. After you have seen all this, my advice is to sleep on it for about a week or, to be more realistic, think about it while lying awake nights; it will help you in keeping awake.

Extent of Work to Be Done

On completion of your week of deliberation the problem now arises as to what is to be done. It is a basic fact that there is no paint presently made which can be successfully applied to rust, scale, tubercles or blisters. It must be in contact with clean iron or with a previously applied coating, tight to the metal and in good condition. Theoretically this clean metal can be obtained by scraping, wire brushing, power sanding or sandblasting. I am opposed to scraping,

as to me it seems a very tedious and uninteresting operation with, at best, only fair results. Power sanding and wire brushing can do a fairly good job if the conditions are not severe. Sandblasting undoubtedly provides the most satisfactory cleaning job, but as is usually the case with the best, is the most expensive. You have now reached the $64.00 question which is the heading of this paragraph, "Extent of work to be done".

There is no mathematical formula which can give you the answer; your good judgment is the formula for this situation. If the paint is hanging in ribbons, exposing a good deal, say one-half or more, of the metal, by all means go to sand blasting. If the annual budget will not allow this, don't do anything for a year or two and wait for finances to catch up with the situation. This is better than spending money on a poor job. If the old coating looks tight, say ¾ of it in good condition, a power brushing with possibly some scraping will prepare these smaller surfaces without too much labor —this is to be followed by a spot priming coat and complete coat of paint.

If your inspection reveals leakage in the seams or rivets, new rivets or caulking the metal is usually the answer. Seams in riveted tanks cannot be welded, because of expansion, resulting in leaks on either side of the weld. If you are confronted with an elevated tank having lattice work on one side of the legs, I do not know of any way to clean the inside of these legs other than by sandblasting. At this point serious consideration should be given to a long-term maintenance program. If the coating on the tank seems to be in a questionable condition, it is probably wise to sandblast down to clean metal and start the program off right. After the initial job, it is advisable to inspect the tank once each year or two and as soon as deterioration of the surface becomes evident, to apply a new coat of paint. A program of this nature results in a small expenditure frequently, but has the advantage of keeping the tank constantly protected and, in the long run, at no greater cost. After possibly 25 years, depending upon frequency of painting, it will become necessary to sandblast again and start the process over.

You should by now have answered the $64.00 question and be in a position to prepare specifications for bids.

Paint

Due to the fact that following me on this program is a paint expert, I am very hesitant to say much on the subject of paint. It is immaterial as to who furnishes the paint, the painting contractor or the water department, but again you should consider the reliability of your contractor. It has been the policy of the American Water Works Co. to submit bids for paint separately, thereby providing their own material. I have followed this practice.

A few notes on paint have come to my attention which may be of interest for what they are worth. You cannot use ordinary lead-oil paints over a previously applied hot tar coating; the material to be used in this case is so-called "Apexia" or its equivalent, which is applied cold, the same as paint.

You cannot apply an ordinary lead-oil paint over graphite paint, as it will not stick. In applying more than one coat they should be of slightly different colors—to expedite complete coverage. Aluminum paint has proven to be most durable for outside coverage.

In Conclusion

I wish to outline my experience with a standpipe which may be a typical case, but in some ways unusual. The tank was erected in Grafton, Mass., for the Grafton Water Co. during the year 1886 under the supervision of my wife's grandfather. It has remained connected with the family ever since, until the year 1953. This standpipe is riveted wrought-iron with a capacity of 100,000 gal, and is 25 ft in diameter by 30 ft tall, with a fixed iron ladder on the outside and a manhole. Even I can climb this one, although I have recently had trouble negotiating the manhole.

When I was given the job of managing this company in 1926, the tank was metal color and had not been painted since 1886; there was no paint on it either inside or out. In 1930 the idea was conceived, not by me, of applying a membrane, resembling burlap, to the interior and covering it with asphalt emulsion, which is a similar procedure to that used in waterproofing flat roofs. At the same time the outside was given a red lead coat, followed by aluminum. The membrane and emulsion lasted about three months, until ice and other non-co-operative conditions brought the membrane and emulsion all

to the bottom. This was shoveled out the next spring without sandblasting. The tank was then painted with the usual red lead primers.

At the beginning of World War Two, leaks began to occur in the bottom ring of plates. Clean, round holes developed, about the size of a pencil, with the resulting stream of water. I made wooden oak plugs and drove them in. This worked out very well until an accumulation of about 15 plugs began to make us wonder how long the tank would last. Because of the war no steel was available and there was considerable anxiety as to results in the town of Grafton, if this tank should suddenly give up. We drained the tank, permanently plugged the holes with iron bolts and applied several coats of the best paint.

About this time, around the middle of the war, the Electro Rustop Co. devised their apparatus to stop corrosion by the so-called cathodic protection method. We immediately purchased one and installed it on the tank. Up to about a year ago no more holes had developed. I have not checked with the superintendent since. My experience with cathodic protection is that it works, but I do not believe it replaces paint. In my estimation it can be compared to a watch-dog, to protect any crack or failure which may develop in the paint coating.

The question of tank maintenance presents many intangible problems and one can argue moneywise as to the merit of not painting at all, as compared to a systematic maintenance and follow-up program.

It is obvious that the time alloted under this afternoon's program cannot permit me much more than to introduce the subject which has the heading of "The Superintendents' Problems". I do hope, however, that some constructive thoughts have been forthcoming, which may be of assistance in planning your future water-tank maintenance.

TANK-PAINT MANUFACTURERS' PROBLEMS IN THE MAINTENANCE OF STEEL WATER-WORKS TANKS

BY CHARLES J. GOTTHARDT*

[*Read February 17, 1955.*]

The protective coatings manufacturer is confronted with several problems in the development of suitable paints for the maintenance of steel water-works tanks. He must produce a paint which (a) controls the mechanism of corrosion, (b) can be applied over various surface conditions, (c) will last a little longer than the owner expects, (d) is easy to apply, priced reasonably, and liked by the applicator, and (e) lastingly improves the appearance of the structure. Usually in problems there is a compromise permissible, but unfortunately for the tank-paint manufacturer, such is not true. Perhaps it is because of these problems that many paint manufacturers do not produce coatings for this purpose. It is a fact that most of these coatings are produced by manufacturers who specialize in corrosion-control paints.

Paint making is an ancient craft, predating history. First evidence of paint is found in the coloration of the scratch drawings of the men of the stone age on their cave walls. In each successive age of man, paint has made a contribution to progress, emerging today as a combination of decorative and protective media, dependent upon other crafts to produce surfaces which are to be decorated or protected, or both.

The underlying theme of the tank-paint manufacturer's problems is the control of the mechanism of corrosion. Now the mechanism of corrosion is not completely understood by science, but the electrochemical interpretation is generally accepted. According to the electrochemical theory, in the case of iron and steel, corrosion is the conversion of metallic iron into iron hydrates of the ferrous or ferric form through the presence of (a) water or moisture, (b) oxygen, and (c) an acid. The actual mechanism of rusting is a primary reaction of iron and water, resulting in the liberation of hydrogen, which in turn is attacked by the oxygen and is thus removed from the surface, leaving hydrated iron oxide—otherwise known as rust.

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With this understanding as fundamental, the knowledge of how certain basic paint chemicals can counteract this process must be utilized. It is fairly obvious that if the three agents of corrosion are denied access to the metal, there will be no corrosion. Hence, the coating must be continuous, so that the metal will be completely isolated mechanically. The coating must also be non-osmotic and non-permeable. But even the most perfect film cannot be expected to do the whole job, for the slightest rupture of the film or imperfection of application would neutralize the entire protective effect. Accordingly, a second line of defense must be incorporated, which will control the corrosive agents through means other than mechanical. This is accomplished by the introduction of certain basic pigments, which possess an oxidizing potential. In the corrosive process, as the iron substratum begins to corrode, ferrous ions are released, which combine with hydroxyl ions in the water, forming ferrous hydroxide. The basic pigments in the paint film cause oxidation of the ferrous hydroxide to ferric hydroxide, which is highly insoluble and is precipitated at the point of formation. Thus, the cathodic potential of the pigment results in the formation of an insoluble film over the anode or corroded area, causing the reaction to be stifled. This double-pronged approach is the basic tactic in the development of a protective coating for water tanks.

When we consider the pigments suitable for this class of service, the well-known rust-inhibiting stand-bys—red lead, blue lead and zinc chromate—must be eliminated for such reasons as solubility, possible toxicity or taste impartment. Remaining are lesser-known inhibitors, such as zinc dust-zinc oxide in combination, basic lead chromate and basic lead silico-chromate. All of these are very active and entirely suitable for tank paints, having none of the undesirable elements of the first-mentioned group.

The relative merit of the acceptable pigments is open to some argument. Based on testing in our laboratory, we rate them as equal rust inhibitors. In the case of basic lead silico-chromate, it is possible to increase the amount of active pigment in a given gallon by virtue of the fact that it is essentially a coating of lead chromate on a core of silica. Since the active portion of any pigment is the surface, it is possible to provide more active area per gallon by coating a light-weight core with a heavy pigment. As lead chromate weighs 56 lb

per solid gallon and basic lead silico-chromate weighs but 34 lb per solid gallon, an appreciation of this advantage is evident. Basic lead silico-chromate is a relatively new development of the National Lead Co., having been on test for several years and now in pilot-plant production. The zinc dust-zinc oxide combination of pigments has been known for many years and is currently the only acceptable pigmentation for water-tank paint on government installations. Its single disadvantage lies in that the zinc dust must be combined with zinc oxide at the time of application.

The development of the continuous film for the mechanical aspect of the protective coating involves consideration of adhesion to steel and to other paint, elasticity under temperatiure changes, abrasion resistance, workability, insensitivity to immersion, and non-permeability. The paint industry and the Federal Government agree that the best all-round film to fit these considerations is produced by a phenolic vehicle. There are many vehicles which approach the 100% phenolic, but all of them are lacking one or more of the fundamental requirements. We feel there is no close second to the phenolic vehicle and, although we are alert to new developments, have seen nothing to date that we would care to consider seriously.

The combining of the pigment with the vehicle completes the basic tactic of tank-paint development, and all that remains to be done is to add the driers, adjust the viscosity, shade to standard color, check the uniformity and conformity to quality control, and to package. All of these steps are standard procedure and have no bearing on the problems in paints for the maintenance of steel water-works tanks.

Manufacturers of paints for water-works service have certain definite ideas how their products should be used. Technically, the responsibility of the manufacturer ceases when his product leaves his hands, because he has no further control over its application and use. His warranty to the customer is limited to the quality and composition of his product. Morally, the manufacturer is extremely interested in how his product is used, for he is interested in seeing the fruit of his labor ripen into satisfied customers through satisfactory performance. Toward this end, the manufacturer first labels his product with a description of the contents and detailed directions for use. Literature is published, describing the products, uses, and method of

application in greater detail, and it is here that the manufacturer makes his plea to do the job his way, in order that the product may serve you well.

Tank paints are system paints in that they require more than a single coat. Usually a painting system provides a particular formulation for the contact with the steel, an identical formulation with a color modification for the intermediate coat and a slightly different formulation for the final coat. For systems involving two coat applications, the second coat ordinarily involves a color change only. On exterior surfaces, the primer is usually the same as applied to the interior, and the intermediate and finish coats are of a different formulation, particularly designed for atmospheric exposure and decorative in appearance. Systems of tank painting may differ, but all manufacturers agree that, whatever system you use, you should be consistent and stay with the same manufacturer's products for the entire job. This is most important, as compatibility of successive paint films is basic to satisfactory performance.

The preparation of the surface in tank-maintenance painting is a phase the paint manufacturer would like to stress, for optimum results rarely can be obtained unless careful and thorough work has preceded the actual spreading of paint. The most desirable surface for repainting is one that has been freshly sandblasted to bright metal. Second choice would be power sanding, wire brushing and scraping to remove all the rust, mill scale, and loose paint. We feel there is no third choice and, therefore, the preparation last mentioned is an absolute minimum. To do less is to invite premature paint failure and to defeat the whole maintenance program.

Paint films for steel water tanks total 0.002″ to 0.003″ in dry thickness, depending on the number of coats applied. On this paper-thin film rests the responsibility for the protection of a major capital investment. The paint manufacturer has poured his knowledge, experience and endless testing into his product, put it into a container and sealed the package. At this point, the manufacturer loses his control over his product, for, from here on, it passes into the hands of the applicator. The performance of the paint will be no better than the applicator's best effort and, conversely, the best application will be unsatisfactory with poor paint. When a tank-paint job fails, there is a quick juggling of responsibility by the manufacturer and the ap-

plicator, and to get at the truth is sometimes exceedingly difficult. Perhaps the paint is wrong, perhaps the application is poor, but more often the real cause of the failure may be traced to the tank owner, who prepared the specifications and let the contract. It is not always sound policy to award a contract to the lowest bidder, unless the specifications are precise and the owner will carefully supervise their adherence. Too often a contract is written and the job completed without the owner's taking the trouble to see that he is getting what he has ordered. Corners can be cut in preparation and application, and paint can be stretched beyond its limit, without its being apparent at the onset. It is not meant that these practices are followed by all or even most applicators, for they know their reputation is at stake. However, the experienced applicators and lowest bidders are not always the same. To help the applicator and the owner insure a good job, as manufacturers we control the degree of hiding in our system paints. Thus, if a coat is over-thinned or stretched out too far, the preceding coat will show through. When spread at the recommended rate, total hiding is achieved.

How long a complete paint job should last on a steel tank in water-works service is a question that must be answered in a "straddle the issue" manner. It is not unusual for a tank to go six years before repainting, but there are extremes on either side of this figure. The expected life of the paint depends on the basic soundness and quality of the paint, the quality of the preparation work, the workmanship of the applicator, the degree of job supervision by the owner, the extremes of temperature, and the chemicals introduced into the water. The most intelligent and, in the long run, the cheapest approach in tank-maintenance painting is not to wait until the film fails before painting, but to anticipate the job with a maintenance program, based on performance experience.

The problems of the paint manufacturer in producing protective coatings for steel water tanks are actually not solvable by him alone. The co-operation of the tank owner and the paint applicator is necessary if practical solutions to all of the problems are to be achieved. It is something of a question of integrity, respect, and confidence in each other. It is a sort of teamwork of a very high order, which works to the benefit of all.

THE PAINTING CONTRACTORS' PROBLEMS IN THE MAINTENANCE OF STEEL WATER-WORKS TANKS

BY ROY O. LEONARD*

[*Read February 17, 1955.*]

I have been sitting here listening to the different problems that arise daily in your own fields. I certainly hope that all or, at any rate, most of them will be eliminated in the near future. I appreciate having this opportunity to tell you about some of the major problems that confront reliable tank painters.

The first problem is that of "Price". As in every field, money is of paramount importance and I cannot impress upon you too strongly the old saying—"You only get what you pay for". You cannot get, or even expect to get, a thorough job, unless the price is commensurate with the work.

Usually, when a municipally owned tank is to be cleaned and painted, specifications are prepared and then invitations to bid are in order. It seems that in most cases the town or city awards the contract to the low bidder. This is unfortunate at times, because there are a few painting contractors who cut the bottom out of the price just to obtain the work. Then—unless an inspector is on the job with them eight hours a day—they are apt to omit a coat of paint or otherwise do a poor job, in order to get out of the contract alive. This is really a problem, as it not only deprives the honest contractor of work, but it hurts the owner, because it will only have to be painted again that much sooner, and makes him disgusted with tank painters in general.

I am not saying that every job we do is 100%, because in painting, as in every field, the human equation enters and things sometimes do not turn out as they should. However, upon being notified, we always try to return and correct the error, and I think a number of you gentlemen will back me up on that statement.

We always advocate that if a town or water district hasn't suffi-

*Contractor, 543 Union Ave., Framingham, Mass.

cient funds in the budget to do the entire job the right way, it is better to do the part that needs the most attention thoroughly and leave the balance until the necessary funds are available.

Another problem we are coming into contact with more and more is that of rigging the interior of some of these newly designed tanks. On some there are hooks welded to the under side of the roof which are of absolutely no value. Some tanks are built with holes in the roof, into which a threaded plug is inserted. Very often these holes are placed in the wrong part of the tank and are of no assistance to the tank painter. It has almost come to a point where the average steeplejack has to be an acrobat in order to paint some of the hard-to-get-at areas. The Factory Mutual Insurance Co. in Boston insists that tanks on property on which they hold the fire insurance be painted and kept in first class condition. I have discussed this matter with their Mr. Sweet several times, and they are quite concerned over the absence of any rigging fixtures. I believe that Mr. Sweet has contacted the tank builders, to try to have some provision inserted in the specifications to take care of this situation.

Then, there is the problem of seepage around the rivet heads and seams. This occurs in older-type tanks and it is virtually impossible to make such a tank 100% water-tight by the chipping and caulking method. We have discussed this matter with various engineering firms and tank manufacturers, but up to this time, the problem is not solved. We have tried blasting all the interior seams and rivet heads to virgin metal, and then brushing on several coats of one of the so-called liquid metals, but even this has not proven 100% satisfactory. We believe that only by welding every seam and rivet head can the tank be made 100% water-tight. Unfortunately to most municipalities the cost of this method is prohibitive.

When painting tanks, the weather is often a major problem. All tank painters know that no paint should be applied when the temperature is below 40°, or in damp and rainy weather. Another effect of the weather encountered while painting a standpipe or elevated tank that is full or partially filled with water, in humid weather, is that of condensation. It is a good practice, if possible, to have the tank emptied. This will eliminate the possibility of the moist warm air's condensing on the cold plates of the tank. This condition is not

as apt to occur on a tank used for sprinkler systems only, because the level and temperature of the water remain constant. However, in the case of a standpipe used on a water-supply system, where cold water is pumped in and out several times a day, the water has no opportunity to establish a temperature balance with the exterior atmosphere. We have had our troubles with condensation and try to avoid them by making sure either that the humidity is very low or that the tank is empty when we paint.

There is another difficulty that we have encountered with many paints on the market today—and that is that they cannot be applied in the late afternoon and still retain their gloss, even though there is no apparent moisture in the air. While this is not a major problem, it does cost the painting contractor a considerable amount of money in the course of a year—repainting these areas.

Before painting a tank, the first problem is in deciding upon the cleaning method to be used for that particular tank. Unless the metal is properly cleaned, it is a waste of money to apply any paint. I shall outline briefly the various methods that we use, in cleaning the surfaces to be painted.

In cases where it is found that the paint film has not broken down, but only blistered and rusted in spots, these spots should be thoroughly cleaned with wire brushes, scrapers or chipping hammers, whichever are necessary. A power wire brush is very effective in many instances. After this type of cleaning, interior areas usually receive two complete coats of paint. Exterior areas are patch-coated and then receive one or two complete coats, as deemed necessary.

However, where the steel is badly pitted and rusted, we believe that sandblasting is the best cleaning method. Sandblasting a surface consists of directing a controlled, fast-moving mixture of sand and air all over the surface to be cleaned. The fast-moving particles strike with such force as to remove all scale, rust, paint and other foreign material, leaving the surface bright and clean.

The sand mixture comes to the operator through a specially constructed ¾″ hose from a container that holds about 800 lb of sand under a pressure of 125 lb per sq in. At the operator's end of the hose, there is a hardened steel or ceramic nozzle, that cuts the ¾″ flow down to a ¼″, causing it to leave the nozzle at a high

velocity and with great cutting power. The average consumption of sand a day is about three tons. It is very important that the area which is sandblasted each day be primed immediately upon completion of blasting.

With regard to new tanks, the plates are usually delivered all de-scaled and primed, with the exception of a 2″ strip around all edges of the plates. This allows an unpainted surface for the welder to work on when joining the various plates together. Upon completion of erection, the welded seams and the 2″ margin around them, together with all abraded spots, must be thoroughly cleaned of rust and slag, and primed with the same make of primer as was used on the balance of the sheet. The tank is then ready for the painter to apply the successive intermediate and finish coats. The kind of paint to use for a given surface used to be quite a problem, but, thanks to great advances in chemical research made by the paint manufacturers, better inhibitive and adhering primers and more pliable paint film, with greater water-excluding qualities, are now available. This means longer life for the paint and greater protection for the surfaces and—in the final analysis—reduced upkeep.

I should like to mention some of the factors involved in the painting of new water tanks. First of all, we must consider the sheets of steel. As they come off the rolling mills, each sheet usually is covered with a thin layer of tightly adhering iron oxides—commonly known as mill scale. It is impossible to roll and fabricate these sheets without cracking this scale. And once it is broken, galvanic action in the presence of moisture starts between the bare metal and the mill scale and spreads rapidly beneath the rest of the scale. Obviously then, to obtain a reliable surface for painting, this scale must be removed. The four methods by which this can be accomplished are as follows:

Sandblasting
Pickling
Flame cleaning
Weathering

Since we have already spoken of sandblasting, I shall proceed with the pickling, which, by the way, is the method most frequently used on steel plates for water tanks. After fabrication, the sheets are

dipped in an acid solution and remain submerged for the length of time necessary to remove all mill scale. After this process, they are rinsed, dried and given a shop coat of primer.

Flame cleaning consists of passing over the surface of the plate with a series of oxyacetylene burners, arranged in the form of a rake. As these burners pass over the surface, the mill scale actually snaps off, due to the differential expansion. In other words, when the intense heat is applied to the mill scale, it expands rapidly and breaks free from the main sheet, which remains comparatively cool. The ideal time to prime is as soon as possible after the removal of scale, while the surface is still warm. This excludes moisture and allows the paint to gain closer contact with the metal.

Weathering as a means of removing mill scale is just as the name implies. After erection the tanks are allowed to remain exposed to the atmosphere for a period of about twelve months. This allows the mill scale to loosen and fall off. Any that is left will usually come off quite easily with a wire brushing. Then the whole surface is given a complete wire brushing and primed.

I appreciate this opportunity of listening to your problems and of trying to give you some idea of the tank painters' problems, and trust that each of us will now have a better understanding of what the other is trying to do.

MEMOIR OF WILLIAM STORRIE

William Storrie, of the Toronto engineering firm of Gore and Storrie, died on May 31, 1955. He was born at Paisley, Scotland, on October 8th, 1883, son of William and Jessie Storrie, and was educated at Paisley Technical College and Glasgow and West of Scotland Technical College.

After early work in Scotland, Mr. Storrie came to Toronto in 1909. He acted as Resident Engineer on the construction of the Toronto water-purification plant and later as Waterworks Engineer for the city of Ottawa. He became Chief Engineer of the John verMehr Engineering Company in 1913.

In 1919 Mr. Storrie became associated with the late William Gore and Dr. George G. Nasmith, when the Consulting Engineering firm of Gore, Nasmith and Storrie was formed. Later the firm became Gore and Storrie and latterly Gore and Storrie, Limited, of which Mr. Storrie was President.

Mr. Storrie was associated in the design and construction of water-works and sewerage projects across Canada, including Toronto, Ottawa, Windsor, Kingston, Belleville, Oshawa, Sudbury, Calgary, Edmonton and many other municipalities. In 1948 he was a member of a Board of three Engineers who made an investigation and report on the water supply and related problems for the city of Detroit. He was actively associated in the planning of a system of water supply and sanitation for the area of Metropolitan Toronto.

Mr. Storrie had been active for many years in various technical associations and societies. He was a past Chairman of the Engineering Institute of Canada. He was best known for his activities in the Canadian Section of the American Water Works Association and the Canadian Institute of Sewage and Sanitation, of which he was past Chairman and past President, respectively. He was formerly Canadian Director of the Federation of Sewage and Industrial Wastes Associations, with which the Canadian Institute of Sewage and Sanitation is affiliated. He had been a member of the New England Water Works Association since 1926.

Mr. Storrie was the only person to receive three of the highest awards for achievement in the water-supply and sanitation field. In 1944 he was awarded the George Warren Fuller Award "for distinguished service and Engineering skill in the field of water supply, for constructive leadership and many contributions to the activities of the Canadian Section of the American Water Works Association". In 1947 he was selected by the Federation of Sewage Works Associations as recipient of the Kenneth Allen Award "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of the Canadian Institute of Sewage and Sanitation". In the same year Mr. Storrie was awarded the Dexter Brackett Memorial Medal by the New England Water Works Association for his paper on the Toronto Water Works Extensions, which was published in the Journal of the Association.

For several years Mr. Storrie lectured to the graduating class of Civil Engineers at the University of Toronto, where his wide experience and sound advice were of great benefit to the young men at the commencement of their engineering careers.

Mr. Storrie's outstanding characteristic was the soundness of his judgment, which was recognized and accepted by all with whom he was associated in his many professional activities. His advice and assistance were always readily available.

His contribution to the development of the water supplies and of the sanitary systems of Canada made him a truly outstanding member of his profession.

NORMAN G. MCDONALD

plicator, and to get at the truth is sometimes exceedingly difficult. Perhaps the paint is wrong, perhaps the application is poor, but more often the real cause of the failure may be traced to the tank owner, who prepared the specifications and let the contract. It is not always sound policy to award a contract to the lowest bidder, unless the specifications are precise and the owner will carefully supervise their adherence. Too often a contract is written and the job completed without the owner's taking the trouble to see that he is getting what he has ordered. Corners can be cut in preparation and application, and paint can be stretched beyond its limit, without its being apparent at the onset. It is not meant that these practices are followed by all or even most applicators, for they know their reputation is at stake. However, the experienced applicators and lowest bidders are not always the same. To help the applicator and the owner insure a good job, as manufacturers we control the degree of hiding in our system paints. Thus, if a coat is over-thinned or stretched out too far, the preceding coat will show through. When spread at the recommended rate, total hiding is achieved.

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*Contractor, 543 Union Ave., Framingham, Mass.

cient funds in the budget to do the entire job the right way, it is better to do the part that needs the most attention thoroughly and leave the balance until the necessary funds are available.

Another problem we are coming into contact with more and more is that of rigging the interior of some of these newly designed tanks. On some there are hooks welded to the under side of the roof which are of absolutely no value. Some tanks are built with holes in the roof, into which a threaded plug is inserted. Very often these holes are placed in the wrong part of the tank and are of no assistance to the tank painter. It has almost come to a point where the average steeplejack has to be an acrobat in order to paint some of the hard-to-get-at areas. The Factory Mutual Insurance Co. in Boston insists that tanks on property on which they hold the fire insurance be painted and kept in first class condition. I have discussed this matter with their Mr. Sweet several times, and they are quite concerned over the absence of any rigging fixtures. I believe that Mr. Sweet has contacted the tank builders, to try to have some provision inserted in the specifications to take care of this situation.

Then, there is the problem of seepage around the rivet heads and seams. This occurs in older-type tanks and it is virtually impossible to make such a tank 100% water-tight by the chipping and caulking method. We have discussed this matter with various engineering firms and tank manufacturers, but up to this time, the problem is not solved. We have tried blasting all the interior seams and rivet heads to virgin metal, and then brushing on several coats of one of the so-called liquid metals, but even this has not proven 100% satisfactory. We believe that only by welding every seam and rivet head can the tank be made 100% water-tight. Unfortunately to most municipalities the cost of this method is prohibitive.

When painting tanks, the weather is often a major problem. All tank painters know that no paint should be applied when the temperature is below 40°, or in damp and rainy weather. Another effect of the weather encountered while painting a standpipe or elevated tank that is full or partially filled with water, in humid weather, is that of condensation. It is a good practice, if possible, to have the tank emptied. This will eliminate the possibility of the moist warm air's condensing on the cold plates of the tank. This condition is not

as apt to occur on a tank used for sprinkler systems only, because the level and temperature of the water remain constant. However, in the case of a standpipe used on a water-supply system, where cold water is pumped in and out several times a day, the water has no opportunity to establish a temperature balance with the exterior atmosphere. We have had our troubles with condensation and try to avoid them by making sure either that the humidity is very low or that the tank is empty when we paint.

There is another difficulty that we have encountered with many paints on the market today—and that is that they cannot be applied in the late afternoon and still retain their gloss, even though there is no apparent moisture in the air. While this is not a major problem, it does cost the painting contractor a considerable amount of money in the course of a year—repainting these areas.

Before painting a tank, the first problem is in deciding upon the cleaning method to be used for that particular tank. Unless the metal is properly cleaned, it is a waste of money to apply any paint. I shall outline briefly the various methods that we use, in cleaning the surfaces to be painted.

In cases where it is found that the paint film has not broken down, but only blistered and rusted in spots, these spots should be thoroughly cleaned with wire brushes, scrapers or chipping hammers, whichever are necessary. A power wire brush is very effective in many instances. After this type of cleaning, interior areas usually receive two complete coats of paint. Exterior areas are patch-coated and then receive one or two complete coats, as deemed necessary.

However, where the steel is badly pitted and rusted, we believe that sandblasting is the best cleaning method. Sandblasting a surface consists of directing a controlled, fast-moving mixture of sand and air all over the surface to be cleaned. The fast-moving particles strike with such force as to remove all scale, rust, paint and other foreign material, leaving the surface bright and clean.

The sand mixture comes to the operator through a specially constructed ¾″ hose from a container that holds about 800 lb of sand under a pressure of 125 lb per sq in. At the operator's end of the hose, there is a hardened steel or ceramic nozzle, that cuts the ¾″ flow down to a ¼″, causing it to leave the nozzle at a high

velocity and with great cutting power. The average consumption of sand a day is about three tons. It is very important that the area which is sandblasted each day be primed immediately upon completion of blasting.

With regard to new tanks, the plates are usually delivered all de-scaled and primed, with the exception of a 2″ strip around all edges of the plates. This allows an unpainted surface for the welder to work on when joining the various plates together. Upon completion of erection, the welded seams and the 2″ margin around them, together with all abraded spots, must be thoroughly cleaned of rust and slag, and primed with the same make of primer as was used on the balance of the sheet. The tank is then ready for the painter to apply the successive intermediate and finish coats. The kind of paint to use for a given surface used to be quite a problem, but, thanks to great advances in chemical research made by the paint manufacturers, better inhibitive and adhering primers and more pliable paint film, with greater water-excluding qualities, are now available. This means longer life for the paint and greater protection for the surfaces and—in the final analysis—reduced upkeep.

I should like to mention some of the factors involved in the painting of new water tanks. First of all, we must consider the sheets of steel. As they come off the rolling mills, each sheet usually is covered with a thin layer of tightly adhering iron oxides—commonly known as mill scale. It is impossible to roll and fabricate these sheets without cracking this scale. And once it is broken, galvanic action in the presence of moisture starts between the bare metal and the mill scale and spreads rapidly beneath the rest of the scale. Obviously then, to obtain a reliable surface for painting, this scale must be removed. The four methods by which this can be accomplished are as follows:

Sandblasting
Pickling
Flame cleaning
Weathering

Since we have already spoken of sandblasting, I shall proceed with the pickling, which, by the way, is the method most frequently used on steel plates for water tanks. After fabrication, the sheets are

dipped in an acid solution and remain submerged for the length of time necessary to remove all mill scale. After this process, they are rinsed, dried and given a shop coat of primer.

Flame cleaning consists of passing over the surface of the plate with a series of oxyacetylene burners, arranged in the form of a rake. As these burners pass over the surface, the mill scale actually snaps off, due to the differential expansion. In other words, when the intense heat is applied to the mill scale, it expands rapidly and breaks free from the main sheet, which remains comparatively cool. The ideal time to prime is as soon as possible after the removal of scale, while the surface is still warm. This excludes moisture and allows the paint to gain closer contact with the metal.

Weathering as a means of removing mill scale is just as the name implies. After erection the tanks are allowed to remain exposed to the atmosphere for a period of about twelve months. This allows the mill scale to loosen and fall off. Any that is left will usually come off quite easily with a wire brushing. Then the whole surface is given a complete wire brushing and primed.

I appreciate this opportunity of listening to your problems and of trying to give you some idea of the tank painters' problems, and trust that each of us will now have a better understanding of what the other is trying to do.

MEMOIR OF WILLIAM STORRIE

William Storrie, of the Toronto engineering firm of Gore and Storrie, died on May 31, 1955. He was born at Paisley, Scotland, on October 8th, 1883, son of William and Jessie Storrie, and was educated at Paisley Technical College and Glasgow and West of Scotland Technical College.

After early work in Scotland, Mr. Storrie came to Toronto in 1909. He acted as Resident Engineer on the construction of the Toronto water-purification plant and later as Waterworks Engineer for the city of Ottawa. He became Chief Engineer of the John verMehr Engineering Company in 1913.

In 1919 Mr. Storrie became associated with the late William Gore and Dr. George G. Nasmith, when the Consulting Engineering firm of Gore, Nasmith and Storrie was formed. Later the firm became Gore and Storrie and latterly Gore and Storrie, Limited, of which Mr. Storrie was President.

Mr. Storrie was associated in the design and construction of water-works and sewerage projects across Canada, including Toronto, Ottawa, Windsor, Kingston, Belleville, Oshawa, Sudbury, Calgary, Edmonton and many other municipalities. In 1948 he was a member of a Board of three Engineers who made an investigation and report on the water supply and related problems for the city of Detroit. He was actively associated in the planning of a system of water supply and sanitation for the area of Metropolitan Toronto.

Mr. Storrie had been active for many years in various technical associations and societies. He was a past Chairman of the Engineering Institute of Canada. He was best known for his activities in the Canadian Section of the American Water Works Association and the Canadian Institute of Sewage and Sanitation, of which he was past Chairman and past President, respectively. He was formerly Canadian Director of the Federation of Sewage and Industrial Wastes Associations, with which the Canadian Institute of Sewage and Sanitation is affiliated. He had been a member of the New England Water Works Association since 1926.

Mr. Storrie was the only person to receive three of the highest awards for achievement in the water-supply and sanitation field. In 1944 he was awarded the George Warren Fuller Award "for distinguished service and Engineering skill in the field of water supply, for constructive leadership and many contributions to the activities of the Canadian Section of the American Water Works Association". In 1947 he was selected by the Federation of Sewage Works Associations as recipient of the Kenneth Allen Award "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of the Canadian Institute of Sewage and Sanitation". In the same year Mr. Storrie was awarded the Dexter Brackett Memorial Medal by the New England Water Works Association for his paper on the Toronto Water Works Extensions, which was published in the Journal of the Association.

For several years Mr. Storrie lectured to the graduating class of Civil Engineers at the University of Toronto, where his wide experience and sound advice were of great benefit to the young men at the commencement of their engineering careers.

Mr. Storrie's outstanding characteristic was the soundness of his judgment, which was recognized and accepted by all with whom he was associated in his many professional activities. His advice and assistance were always readily available.

His contribution to the development of the water supplies and of the sanitary systems of Canada made him a truly outstanding member of his profession.

NORMAN G. MCDONALD

PROCEEDINGS

April 1955 Meeting

Hotel Statler, Hartford, Conn.

Thursday, April 21, 1955

Despite inclement weather, 160 members and guests of the New England Water Works Association attended the meeting, which was preceded by an inspection tour of the filtration plant and reservoir in West Hartford.

Luncheon was served in the ballroom of the Hotel Statler, after which President Roger G. Oakman introduced those at the head table. President Oakman then called upon the Hon. John T. Welles, Vice-Chairman of the Metropolitan District Commission and Chairman of its Water Bureau, who was most cordial in his welcome to the group.

An illustrated paper, "Metropolitan District Sources of Water Supply", was read by Warren A. Gentner, Deputy Manager and Chief Engineer of the Water Bureau of the Metropolitan District, Hartford, Conn.

An illustrated paper, "Construction of the East Transmission Main in Hartford and East Hartford", was read by Gilbert U. Gustafson, Associate Chief Designing Engineer, Water Bureau of the Metropolitan District, Hartford, Conn.

May 1955 Meeting

Rovelli's Restaurant, Springfield, Mass.

Thursday, May 19, 1955

The new plant of the Lock Joint Pipe Co. in Westfield, Mass., and the laying of pipes in Springfield were the objects of inspection by some 185 members and guests of the New England Water Works Association.

The group met for luncheon at Rovelli's Restaurant in Springfield, after which President Roger G. Oakman introduced those at the head table. He called upon the Hon. Daniel B. Brunton, Mayor of the city of Springfield, and the Hon. Alice Burke, Mayor of the city of Westfield, and both were most cordial in their welcoming remarks.

An illustrated paper, "Meeting Accelerated Industrial Demands in Springfield", was read by Peter C. Karalekas, Chief Water Engineer, Municipal Water Works, Springfield, Mass.

An illustrated paper, "Manufacture of Prestressed Concrete Pipe", was read by Robert E. Bald, Assistant Chief Engineer, Lock Joint Pipe Co., East Orange, N. J.

INDEX OF ADVERTISERS

	Page
Anderson-Nichols & Co.	iii
Badger Meter Mfg. Co.	Following front cover
Bahr, Ray	xx
B-I-F Industries, Inc.	Following front cover
Bingham & Taylor Corp.	Following front cover
Brown Co.	xx
Camp, Dresser & McKee	ii
Cast Iron Pipe Research Assn.	xxvii
Cement Lined Pipe Co.	xx
Centriline Corp.	Following front cover
Chapman Co., R. E.	ii
Chicago Bridge & Iron Co.	xxi
Coffin and Richardson	ii
Crosby, Irving B.	ii
Dresser Mfg. Div.	xxx
Eddy Valve Co.	xiv
Eureka Pipe Co., Inc.	xvi
Fairbanks, Morse & Co.	Following front cover
Fay, Spofford & Thorndike	ii
Flexible Sales Corporation	xx
Ford Meter Box Co., The	Following front cover
Gunite Restoration Co., Inc.	ii
Haley & Ward	ii
Hays Mfg. Co.	xv
Hazen & Sawyer	iii
Hersey Mfg. Co.	iv
Hilco Supply, Inc.	xxi
Hydraulic Development Corp.	iv
Johns Manville Sales Corp.	x
Keasbey & Mattison Co.	vii
Kennedy Valve Mfg. Co.	xxii
Koppers Co., Inc.	xxix
Knowles, Inc., Morris	ii
Layne-New York Co.	iii
Leadite Co.	Back cover
Leggette, Brashears & Graham	ii
Lock Joint Pipe Co.	Following front cover
Maguire & Assoc., Chas. A.	iii
Maher Co., D. L.	iii
Metcalf & Eddy	ii
Mills Engineering Co., Inc.	xvi
Morris Knowles, Inc.	ii
Mueller Co.	Following front cover
National Water Main Cleaning Co.	xii
Neptune Meter Co.	xi
Pierce-Perry Co.	iii
Pipe Founders Sales Corp.	xvi
Pirnie, Malcolm	iii
Pitometer Assoc., Inc., The	iii
Pittsburgh-Des Moines Steel Co.	Following front cover
Pittsburgh Equitable Meter Div.	Following front cover
Pollard Co., Inc., Joseph G.	Following front cover
Pratt Co., Henry	vi
Prescott & Sons, Inc., H. R.	xviii
Public Works Supply Co.	xx
Rensselaer Valve Co.	v
Ross Valve Mfg. Co.	xix
Smith Mfg. Co., The A. P.	Following front cover
Torrington Supply Co., Inc.	xxii
Turbine Equipment Co. of New England	Following front cover
U. S. Cast Iron Pipe & Foundry Co.	xxviii
Utilities Supply Corp.	xxii
Wallace & Tiernan Co., Inc.	xiii
Warren Foundry & Pipe Corp.	Following front cover
Weston & Sampson	iii
White Construction Co., R. H.	xvi
Whitman & Howard	iii
Wood Co., R. D.	Following front cover
Worthington-Gamon Meter Div.	viii

(Classified index on page xxiii)

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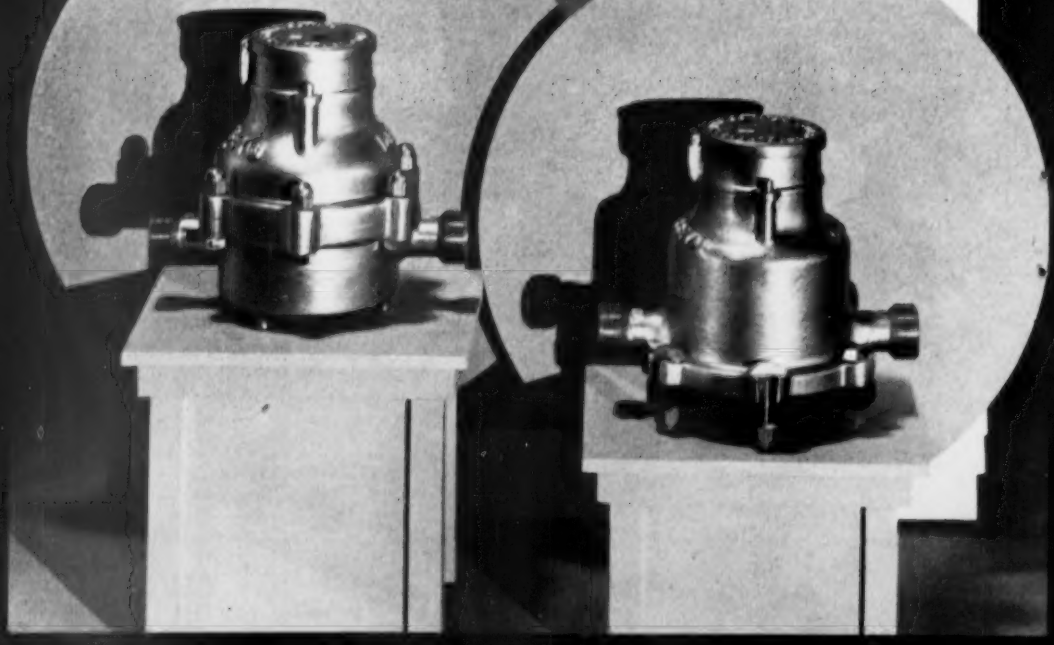
1955



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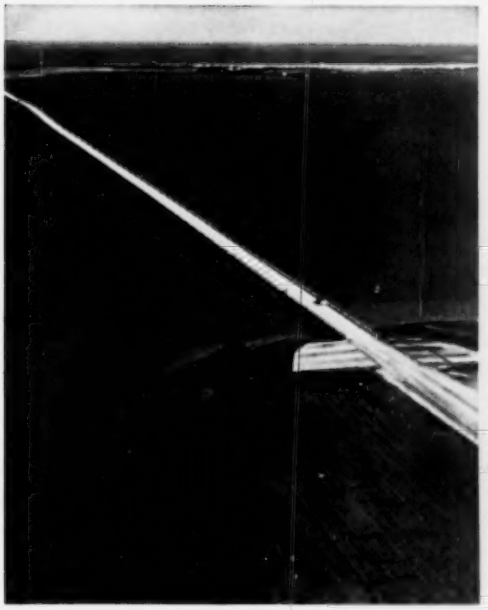
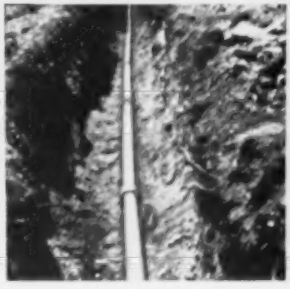


Seafaring durability! K&M "Century" Pipe "goes to sea" on the Padre Island causeway pictured here. The island is located off the Texas mainland. Engineers: Parson, Brinckerhoff, Hall and Macdonald, New York. Installation contractor: W. T. Liston Co., Harlingen, Texas. Photo by Booth Studio.

In the south! "Century" Pipe is shown here at the beginning of the Padre Island causeway—a span that stretches out from the coast of Texas into the Gulf of Mexico for a mile and a quarter.



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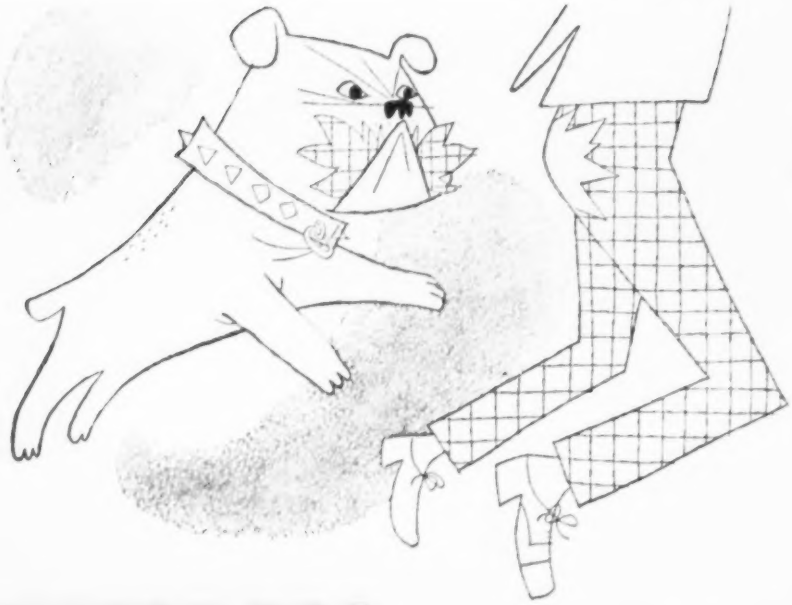

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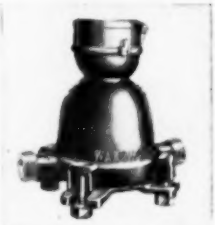

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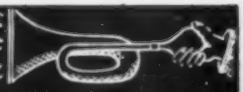

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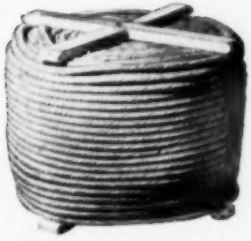

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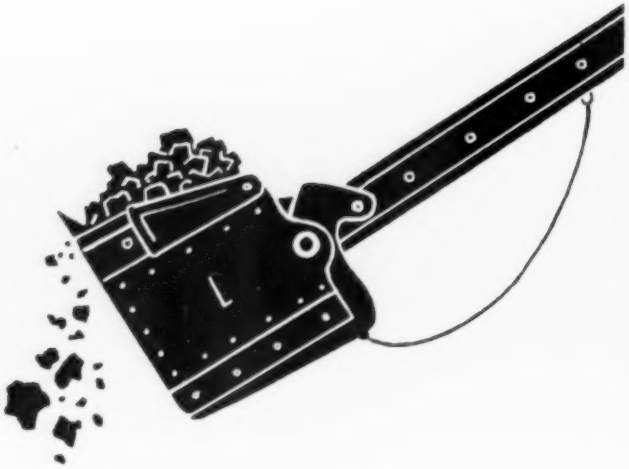

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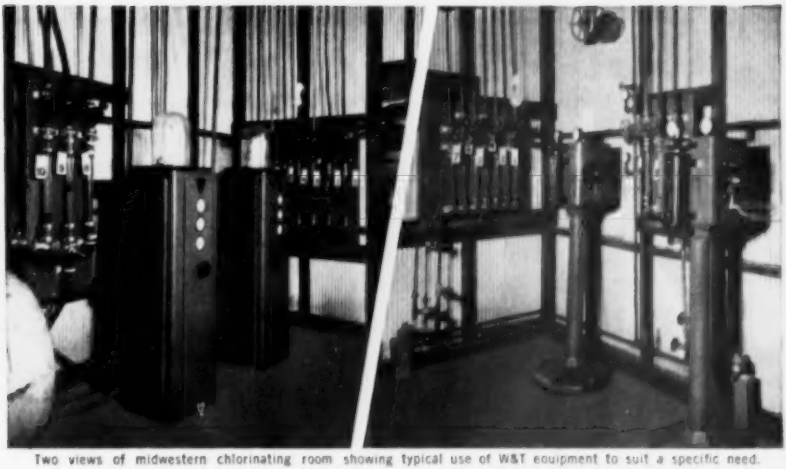

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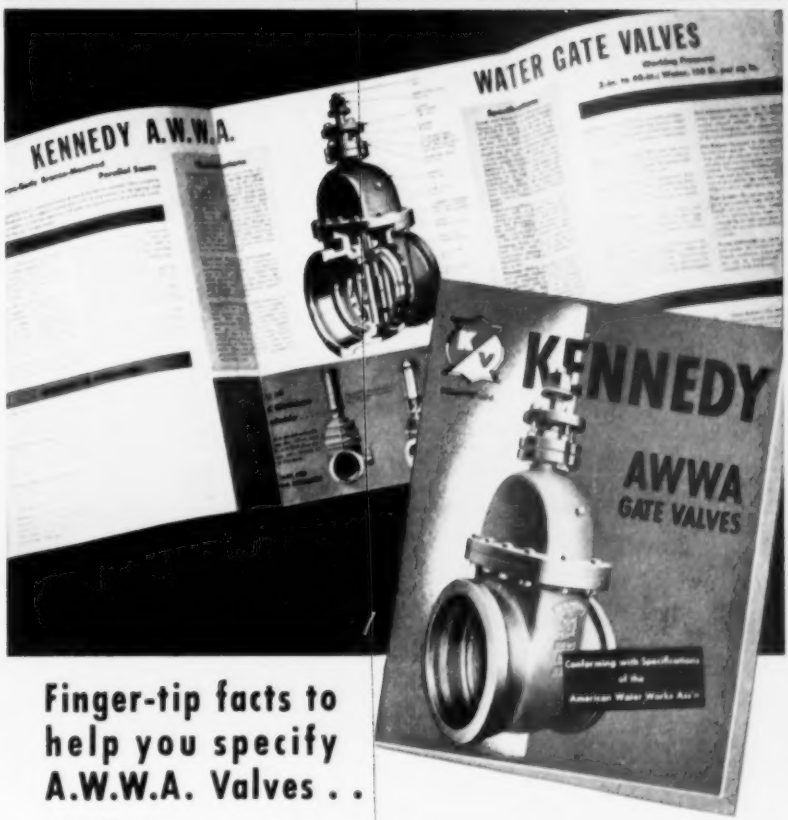

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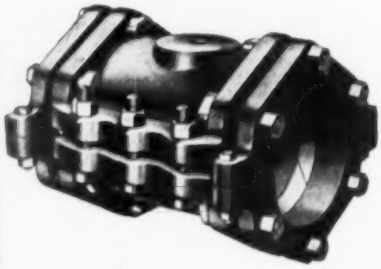

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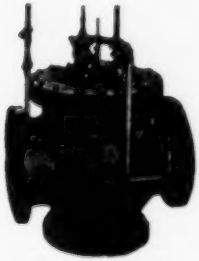

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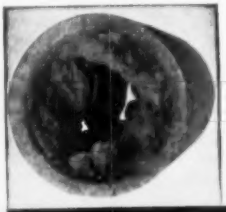

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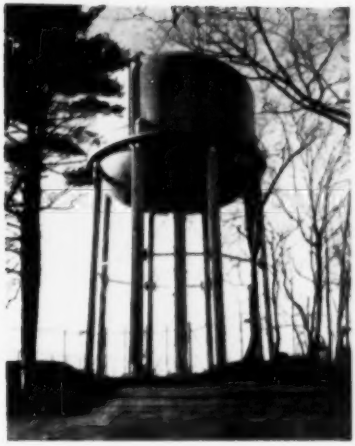

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CLASSIFIED DIRECTORY OF ADVERTISEMENTS

ASBESTOS-CEMENT PIPE.
Kensbey & Mattison Company ... vii

BRASS GOODS.
Eureka Cement Lined Pipe Co. ... xvi
Hilco Supply ... xxi
Mueller Co. ... Following front cover
Pierce-Perry Co. ... iii
Torrington Supply Co., Inc. ... xxii
Utilities Supply Corp. ... xxii

CALKING MACHINERY AND TOOLS.
Hydraulic Development Corp. ... ix
Mueller Co. ... Following front cover

CAST IRON PIPE. (See Pipe, Cast Iron.)

CEMENT LINED PIPE. (See Pipe, Cement Lined.)

CHEMICAL FEED APPARATUS.
B-I-F Industries ... Following front cover
Wallace & Tiernan Co., Inc. ... xiii

CHLORINATORS.
B-I-F Industries ... Following front cover
Wallace & Tiernan Co., Inc. ... xiii

CLARIFIERS.
Mills Engineering Co., Inc. ... xvi

CLEANING WATER MAINS.
Flexible Pipe Cleaning Co. ... xx
National Water Main Cleaning Co. ... xii

COCKS, CURBS AND CORPORATIONS.
Eureka Cement Lined Pipe Co. ... xvi
Hays Mfg. Co. ... xv
Mueller Co. ... Following front cover
Pierce-Perry Co. ... iii

CONCRETE PIPE. (See Pipe, Concrete.)

CONTRACTORS' EQUIPMENT.
Hydraulic Development Corp. ... ix

CONTRACTORS.
Layne-New York Co., Inc. ... iii
Maher, D. L. Co. ... iii
White Construction Co., R. H. ... xvi

COUPLINGS, FLEXIBLE PIPE.
Public Works Supply Company ... xx

CURB BOXES.
Eureka Cement Lined Pipe Co. ... xvi
Hays Mfg. Co. ... xv
Hilco Supply ... xxi
Mueller Co. ... Following front cover
Pierce-Perry Co. ... iii
H. R. Prescott & Sons, Inc. ... xviii
Public Works Supply Company ... xx

DIAPHRAGMS, PUMPS.
Joseph G. Pollard Co. ... Following front cover
% Proportioneers, Inc. % (B-I-F Industries, Inc.) ... Following front cover

EJECTOR, PNEUMATIC.
Mills Engineering Co., Inc. ... xvi

ENGINEERS.
Anderson-Nichols & Co. ... iii
Camp, Dresser & McKee ... ii
Coffin & Richardson ... ii
Crosby, Irving B. ... ii
Fay, Spofford and Thorndike ... ii
Haley and Ward ... ii
Hazen and Sawyer ... iii
Knowles Morris, Inc. ... ii
Leggette, Brashears & Graham ... ii
Maguire & Associates, Charles A. ... iii
Metcalf and Eddy ... ii
Pirnie Engineers, Malcolm ... iii
Pitometer Associates, Inc., The ... iii
Weston and Sampson ... iii
Whitman and Howard ... iii

ENGINES. (See Pumps and Pumping Engines.)

EQUIPMENT. (See Contractors' Equipment.)

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

FEED WATER FILTERS.
- % Proportioneers, Inc. % (B-I-F Industries, Inc.) ..... Following front cover
- Ross Valve Mfg. Co., Inc. xix

FILTRATION PLANT EQUIPMENT.
- B-I-F Industries ..... Following front cover
- Mills Engineering Co., Inc. xvi

FLAP VALVES.
- Eddy Valve Co. xiv

FLEXIBLE JOINTS.
- Dresser Mfg. Div. xxx
- U. S. Pipe and Foundry Co. xxviii

FURNACES.
- Hilco Supply xxi
- Hydraulic Development Corp. ix
- Leadite Co., The ..... Back cover
- Mueller Co. ..... Following front cover
- Pollard Co., Joseph G. ..... Following front cover
- H. R. Prescott & Sons, Inc. xviii
- Public Works Supply Company xx

GAS HOLDERS.
- Chicago Bridge and Iron Co. xxi

GATE VALVES. (See Valves.)

GEARS.
- Mills Engineering Co., Inc. xvi

GUNITE CONSTRUCTION.
- Gunite-Restoration Co., Inc. ii

HOSE, SUCTION AND CONDUCTION.
- H. R. Prescott & Sons, Inc. xviii

HYDRANTS, FIRE.
- Eddy Valve Co. xiv
- Hilco Supply xxi
- Kennedy Valve Mfg. Co. xvii
- Mueller Co. ..... Following front cover
- H. R. Prescott & Sons, Inc. xviii
- Public Works Supply Company xx
- Rensselaer Valve Co. v
- Smith Mfg. Co., The A. P. ..... Following front cover
- Utilities Supply Corp. xxii
- Wood, R. D., Co. ..... Following front cover

HYDRANTS, PUMPS.
- Hilco Supply xxi
- Joseph G. Pollard Co. ..... Following front cover
- H. R. Prescott & Sons, Inc. xviii

LEAD PIPE. (See Pipe, Lead.)

LIQUID CHLORINE.
- Brown Co. xx

METERS, OIL AND WATER.
- Badger Meter Mfg. Co. ..... Following front cover
- B-I-F Industries ..... Following front cover
- Hersey Mfg. Co. iv
- Neptune Meter Co. xi
- Pipe Founders Sales Corp. xvi
- Pittsburgh Equitable Meter Div. ..... Following front cover
- Worthington-Gamon Meter Div. viii

METER COUPLINGS.
- Badger Meter Mfg. Co. ..... Following front cover
- Ford Meter Box Co. ..... Following front cover
- Hays Mfg. Co. xv
- Hersey Mfg. Co. iv
- Mueller Co. ..... Following front cover
- Neptune Meter Co. xi
- Public Works Supply Company xx
- Worthington-Gamon Meter Div. viii

METERS (Venturi Type.)
- B-I-F Industries ..... Following front cover

METER BOXES.
- Bingham & Taylor Corp. ..... Following front cover
- Ford Meter Box Co. ..... Following front cover
- Mueller Co. ..... Following front cover
- Public Works Supply Company xx

METER TESTERS.
- Badger Meter Mfg. Co. ..... Following front cover
- Ford Meter Box Co. ..... Following front cover
- Mueller Co. ..... Following front cover
- Neptune Meter Co. xi
- Public Works Supply Company xx

OIL ENGINES.
- Fairbanks, Morse & Co. ..... Following front cover

PIPE, ASBESTOS-CEMENT.
- Keasbey & Mattison Company vii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

PIPE, BRASS.
Hilco Supply xxi
Pierce-Perry Co. iii
H. R. Prescott & Sons, Inc. xviii
Torrington Supply Co., Inc. xxii
Utilities Supply Corp. xxii

PIPE, CAST IRON (and Fittings.)
B-I-F Industries ..... Following front cover
Bingham & Taylor Corp. ..... Following front cover
Cast Iron Pipe Research Association xxvii
Dresser Mfg. Div. xxx
Hilco Supply xxi
Pipe Founders Sales Corp. xvi
H. R. Prescott & Sons, Inc. xviii
U. S. Pipe and Foundry Co. xxviii
Utilities Supply Corp. xxii
Warren Foundry and Pipe Co. ..... Following front cover
Wood, R. D., Co. ..... Following front cover

PIPE, CEMENT LINED.
Cast Iron Pipe Research Association xxvii
Cement Lined Pipe Co. xx
Eureka Cement Lined Pipe Co. xvi
Pipe Founders Sales Corp. xvi
U. S. Pipe and Foundry Co. xxviii

PIPE, COATING AND LININGS.
Centriline Corp. ..... Following front cover
Koppers Co., Inc. xxix

PIPE, CONCRETE.
Lock Joint Pipe Co. ..... Facing front cover

PIPE CUTTING MACHINES.
Pollard Co., Joseph G. ..... Following front cover
Smith Mfg. Co., The A. P. ..... Following front cover

PIPE JOINTING MATERIAL.
Hilco Supply xxi
Hydraulic Development Corp. ix
Leadite Co., The ..... Back cover

PIPE, LEAD.
Pierce-Perry Co. iii

PIPE LINING.
Cement Lined Pipe Co. xx
Centriline Corp. ..... Following front cover

PIPE, PRESTRESSED CONCRETE.
Lock Joint Pipe Co. ..... Facing front cover

PIPE, WROUGHT IRON AND STEEL.
Pierce-Perry Co. iii
Torrington Supply Co., Inc. xxii

PLUG VALVES.
Eddy Valve Co. xiv
Hays Mfg. Co. xv
Mueller Co. ..... Following front cover
Pittsburgh Equitable Meter Div. ..... Following front cover

PITOMETERS.
Pitometer Associates, Inc., The iii

PORTABLE AIR COMPRESSORS. (See Air Compressors.)

PRESSURE REGULATORS.
Hilco Supply xxi
Mueller Co. ..... Following front cover
Pittsburgh Equitable Meter Div. ..... Following front cover
H. R. Prescott & Sons, Inc. xviii
Ross Valve Mfg. Co., Inc. xix

PROVERS, WATER.
Badger Meter Mfg. Co. ..... Following front cover
Ford Meter Box Co. ..... Following front cover

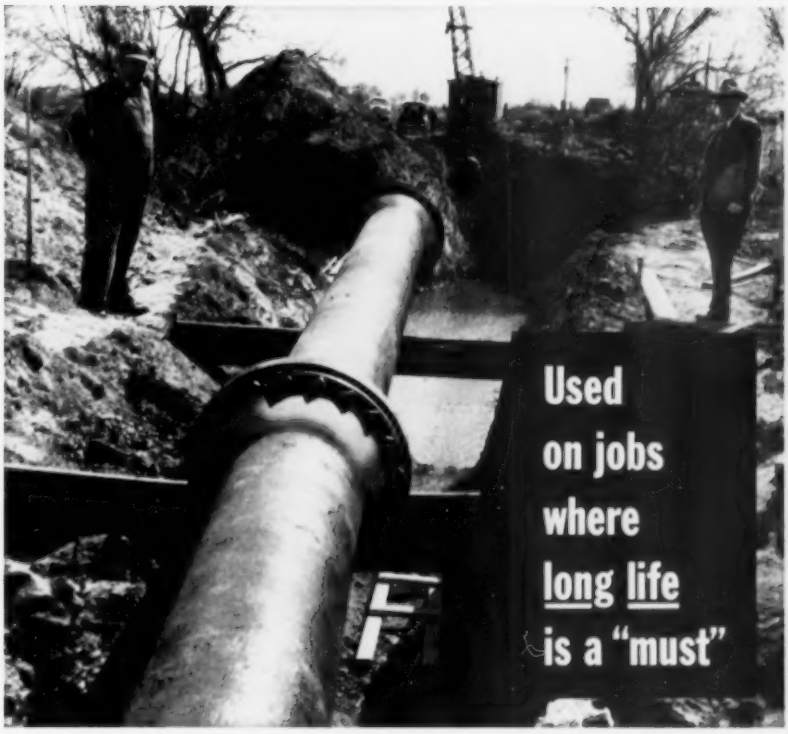
PUMPS AND PUMPING MACHINES.
Fairbanks, Morse & Co. ..... Following front cover
Layne-New York Co., Inc. iii
Hilco Supply xxi
Maher Co., D. L. iii
Mills Engineering Co., Inc. xvi
Joseph G. Pollard Co. ..... Following front cover
H. R. Prescott & Sons, Inc. xviii
Ross Valve Mfg. Co., Inc. xix
Turbine Equipment Co. ..... Following front cover
White Construction Co., R. H. xvi

RATE CONTROLLERS AND GAUGES.
Badger Meter Mfg. Co. ..... Following front cover
B-I-F Industries ..... Following front cover

REDUCERS, SPEED.
Mills Engineering Co., Inc. xvi

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

SHEAR GATES.
Eddy Valve Co. xiv
Mueller Co. ..... Following front cover
SLEEVES AND VALVE TAPPINGS.
Eddy Valve Co. xiv
Hilco Supply xxi
Mueller Co. ..... Following front cover
H. R. Prescott & Sons, Inc. xviii
Public Works Supply Company xx
Rensselaer Valve Co., Inc. v
Smith Mfg. Co., The A. P. ..... Following front cover
STAND PIPES.
Chicago Bridge and Iron Co. xxi
STEEL PLATE WORK.
Chicago Bridge and Iron Co. xxi
Pittsburgh-Des Moines Steel Co. ..... Following front cover
STRAINERS.
Mills Engineering Co., Inc. xvi
SUPPLIES AND TOOLS.
Hilco Supply xxi
Hydraulic Development Corp. ix
Leadite Co., The ..... Back cover
Mueller Co. ..... Following front cover
Pierce-Perry Co. iii
Pollard Co., Joseph G. ..... Following front cover
H. R. Prescott & Sons, Inc. xviii
Public Works Supply Company xx
TAPPING MACHINES.
Hays Mfg. Co. xv
Mueller Co. ..... Following front cover
Smith Mfg. Co., The A. P. ..... Following front cover
TANKS, STEEL.
Chicago Bridge and Iron Co. xxi
Pittsburgh-Des Moines Steel Co. ..... Following front cover
TAPPING SLEEVES. (See Sleeves and Valves, Tappings.)
VALVE BOXES.
Bingham & Taylor Corp. ..... Following front cover
Eddy Valve Co. xiv
Hilco Supply xxi
Kennedy Valve Mfg. Co. xvii
Mueller Co. ..... Following front cover
Pierce-Perry Co. iii
Pipe Founders Sales Corp. xviii
H. R. Prescott & Sons, Inc. xviii
Public Works Supply Company xx
Smith Mfg. Co., The A. P. ..... Following front cover
Wood, R. D., Co. ..... Following front cover
VALVES, BUTTERFLY.
Henry Pratt Co. vi
VALVE AND GATE GENERATORS.
Mills Engineering Co., Inc. xvi
VALVE INSERTING MACHINES.
Mueller Co. ..... Following front cover
Smith Mfg. Co., The A. P. ..... Following front cover
VALVES, CHLORINE.
Wallace & Tiernan Co., Inc. xiii
VALVES, GATE.
Eddy Valve Co. xiv
Hilco Supply xxi
Kennedy Valve Mfg. Co. xvii
Mueller Co. ..... Following front cover
Pierce-Perry Co. iii
H. R. Prescott & Sons, Inc. xviii
Public Works Supply Company xx
Rensselaer Valve Co. v
Smith Mfg. Co., The A. P. ..... Following front cover
Torrington Supply Co., Inc. xxii
Wood, R. D., Co. ..... Following front cover
VALVES, REGULATING.
Mueller Co. ..... Following front cover
Ross Valve Mfg. Co., Inc. xix
WASH FOUNTAINS.
Mills Engineering Co., Inc. xvi
WATER-PROOFING.
Gunite Restoration Co., Inc. ii
WATER WASTE DETECTION.
Pitometer Associates, Inc., The iii
WELLS, GRAVEL, FILTER AND DRIVEN.
Layne-New York Co., Inc. iii
Maher Co., D. L. iii
WROUGHT IRON PIPE. (See Pipe, Wrought Iron and Steel.)



Installing cast iron mechanical joint pipe across river at Salina, Kansas, for sewer main.

When an installation, once completed, should be as trouble-proof as planning and materials can make it — engineers rely on cast iron pipe. It has high beam-strength, compressive-strength and shock-strength. Its effective resistance to corrosion ensures long life, underground or underwater. These are reasons why cast iron pipe is so widely used for water lines in tough terrain, pressure and outfall sewers, river crossings, and encased piping in sewage treatment and water filtration plants. Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 122 So. Michigan Ave., Chicago 3, Ill.

This 123-year-old cast iron water main is still in use in the distribution system of St. Louis, Mo.

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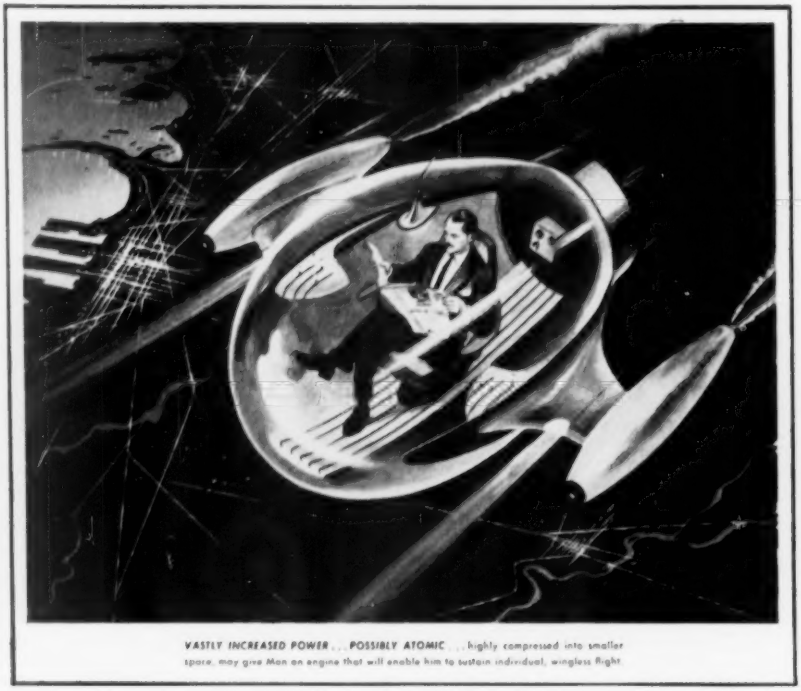

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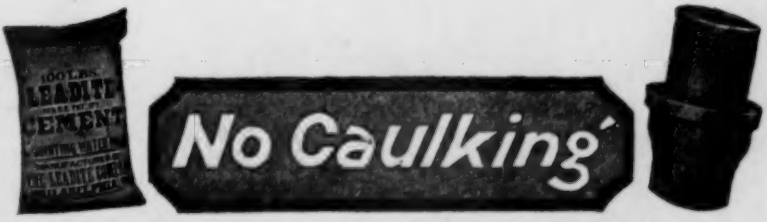
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